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USE OF THE SURVEY METHOD IN HORTICULTURAL RESEARCH[1]

J. C. WILCOX[2]

Dominion Experimental Station, Summerland, B.C.

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PURPOSE OF A HORTICULTURAL SURVEY

The survey method has been widely used in horticultural research. Little appears to have been published, however, on the specific advantages and disadvantages of this method of horticultural research, as compared with more exact methods. This paper constitutes a discussion of the method and its usefulness, as revealed in several investigations conducted by the author and his co-workers.

The purpose of a survey can be twofold. First, it can be used to determine the numerical distribution of classes of individuals. For example, a survey might be conducted to determine the number of fruit trees of each kind and variety that are present in certain areas at any one time. It could be amplified to include such factors as size of tree, condition of tree, yield, etc. The major purpose, however, would be a mere recording of facts. It would be necessary either to record every individual tree in the areas concerned, or to sample the orchards or the trees in a representative manner, so that the data obtained could be considered a reliable index of the total.

In the second place, the survey method can be used for the purpose of determining relationships between factors and functions, between causes and effects. For example, it may be desired to determine whether any relationship exists between soil texture (a factor) and yield of apple trees (a function) under field conditions, or between the crop on a tree (factor) and the length of the terminal shoots the same year (function). The major purpose would be to discover more-or-less fundamental laws or relationships that could be applied at any time under the same or similar circumstances. It would not be necessary to sample the available population in such a manner as to represent the whole population proportionately; in some cases at least, it would probably be more important to make certain that the samples be taken so as to represent a wide range of each of the factors under consideration. For example, in studying the relationships between soil texture and tree yield, it would seem advisable to take texture and yield records under a wide range of soil textural classes. This type of survey may not be considered a survey in the true sense of the word. There does not appear to be any better word, however, to describe it.

[1] Contribution No. 727 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Officer in charge of Soils and Plant Nutrition Laboratory, Dominion Experimental Station, Summerland, B.C.

These two purposes of a survey can be accomplished separately or together. In the investigations that form the basis of this discussion, the second purpose was the primary one; and any information obtained that would satisfy the first purpose can be considered only incidental.

Whatever the purpose of a field survey, it is usually necessary to sample a comparatively large number of individuals. For example, it would not be sufficient to record the yield of one apple tree growing on each of five soil textures, and to come to conclusions on the basis of this sample. Perhaps a total of 100 or more trees would be required. As will be made clear in the discussion to follow, the reasons for this are field variability and the large number of factors concerned.

SOURCES OF MATERIAL

The sources of material that are used as a basis for this discussion are as follows:—

1. Studies of the relationships between, and the value of, different methods of expressing tree vigour. In a series of investigations, the relationships among trunk circumference, annual increase in trunk circumference, terminal shoot length and diameter, percentages of bloom and set of fruit, and yield, were studied over a period of years on apple trees. The initial results, on 58 McIntosh trees, were reported in 1937 (2, 3, 4).

2. Studies of the relationships between field measurements and laboratory measurements of soil moisture, using 100 soil samples collected at the field capacity for moisture in several soil series. Data were obtained, on each sample, of moisture holding capacity, wilting coefficient, available moisture content, percentages of sand, silt, clay and colloid, and settling volume. The results were reported in 1941 (6, 7). A second investigation of similar nature, using 93 soil samples, was reported in 1949 (14).

3. Studies of some factors affecting apple yields. Mature McIntosh trees were selected in different soil series in different districts in the Okanagan Valley, to a total of 400 trees in 85 groups of five or less. This was later reduced to 290 trees in 73 groups or plots. A deliberate attempt was made to include wide variations in soil texture, soil depth, fertilizer treatment and cultural methods. Soil and twig samples were analysed for N, P, K, Ca and Mg; determinations were made of the pH, salt content, lime content, organic matter content, and sand, silt, clay and colloid contents of the soil; root counts were made; and records were taken over a six-year period on tree size, tree spacing, increase in trunk circumference, terminal length, yield and grade of fruit. The relationships among most of these factors have now been studied, and have been reported in a series of papers (5, 8, 9, 10, 11, 12, 13). The findings of this investigation have provided the major source of material for the present discussion.

In all of these investigations, the relationships among the various sets of records have been determined primarily by means of the coefficient of correlation. Scatter diagrams have been freely used to assist in explaining the correlations. In many cases, the effects of one or more factors on a correlation have been eliminated by calculation of partial coefficients of correlation. Where it has appeared advisable to eliminate the effects of

more than two factors (as in the third investigation), coefficients of regression have been determined, the yield or other function has been corrected tree by tree for variations in each factor in turn, and the adjusted yields have then been correlated with the next factor under consideration. In some cases, the analysis of covariance procedure has been used (1). These procedures will be referred to further in the discussion below.

SOME PROBLEMS ENCOUNTERED

Many problems were encountered in the investigations noted above. Some of these problems were solved, others were not. Among the more difficult problems were those associated with the selection of materials, the sampling, measuring and recording, and the interpretation of results.

Selection of Materials

It was recognized at the start of each investigation that each measurement would be affected by a large number of factors, and that it would be advisable to select the materials in such a manner as to eliminate as many as possible of those factors not pertinent to the investigation. This was especially true in the apple investigation. Here all nutritional factors were considered to be of especial interest, while other factors were not; hence it was decided to record all nutritional factors as far as time and expense would permit, and where feasible to ignore the other factors.

It was not found feasible, in the apple investigation, to record all of the nutritional factors. This was due partly to lack of time and partly to the fact that there were too many nutritional factors to be studied all at once. Some were ignored, (such as minor elements), on the assumption that they were unimportant; but whether or not they were actually unimportant was not determined. One serious problem was encountered in connection with the soil moisture status. An attempt was made to eliminate any major effects of soil moisture by selecting only orchards where the moisture content was maintained at "adequate" levels, i.e. between field capacity and the wilting point. Although a careful watch was maintained on irrigation procedures, it appeared quite possible that adequate soil moisture contents were actually not maintained in every case.

Neither was it found feasible, in the apple investigation, to ignore all of the non-nutritional factors. It was foreseen that some of them would have major effects on the growth and yield of the trees. In certain cases, it was found possible to measure some of these factors, as in the case of size of tree and distance of planting. In other instances, an attempt was made to minimize the effects of the factors in the selection of material. For example, only one variety of apple was used, the McIntosh; only trees that appeared to be in good health were selected, thus minimizing the effects of diseases, insect pests, and winter injury; and only those orchards were selected in which the trees appeared to receive good care as far as thinning, pruning, spraying, etc., were concerned. These precautions assisted greatly in reducing the effects of non-nutritional factors. However, during the course of the investigation it became apparent that the yield or quality of fruit in many cases was being reduced by crown rot, oyster-shell scale, leaf hoppers, poor pruning, poor thinning or other factors. Where this was recognized,

such trees in most cases were eliminated from the experiment, so that the original 400 trees were reduced to 290. It is quite possible that in many cases the yield or quality was reduced by factors not measured and not even recognized.

In the slection of materials, it was considered advisable to include a wide range of each of the major factors under consideration. For example, in the apple investigation, groups of trees were located in a wide range of soil textures, soil depths, and fertilizer treatments. This did not constitute a serious problem. In the other investigations, also, no serious difficulty was encountered in obtaining a wide range of the factors being studied.

Recording and Sampling

Owing to the field variability encountered, it was not considered necessary to be absolutely accurate in the recording of the field data. In the apple investigation, for example, yields were recorded in bushel boxes, to the nearest half-box; shoot growth was added on a steel tape, and the total per tree recorded to the nearest centimetre; and tree spacing was measured to the nearest foot. The results obtained indicated that additional accuracy would have been superfluous.

Because of the many factors affecting fruit tree performance, it was considered advisable to select a large number of trees on which to take records. This increased greatly the work of recording and sampling. It was not found possible always to be at the right place at the right time. The chief difficulty encountered in this respect was in recording the yield per tree, as the operator could not be present in all 73 plots throughout the length of the Okanagan Valley at the same time; hence it was necessary to obtain the assistance of the fruit-growers in the recording. For the most part they did a good job, but in some cases they did not. Errors in recording of the yield were revealed by individual tree estimates made beforehand; nevertheless, this did constitute a source of error. It was found necessary to discard some of the yield records.

One of the greatest sources of error in field work is inadequate sampling, especially of the soil and of plant tissues. In the apple investigation, soil samples were taken around an individual tree in each plot, each composite being obtained from ten locations. This was adequate for these individual trees, but not always for the whole plots. Soil variations were sometimes great within individual plots.

Interpretation of Results

The interpretation of results is one of the most difficult steps in an investigation of this nature. The difficulty arises chiefly from the large number of factors entering into the results. This holds true even when some factors have been largely eliminated by care in the selection of material. In these investigations, some of the factors affecting the results have been measured, some have not. When they have not been measured, there has been no way of adjusting for their variability. And even when they have been measured, their effects on one another and on the function (e.g. yield) have been so interrelated and complex that satisfactory segregation of individual relationships has sometimes been almost impossible.

The correlation procedure, supported by scatter diagrams, has formed the statistical basis for the studies discussed herein. In some cases, simple correlations gave the desired information. For example, in the first soil moisture studies the correlation between percentage colloid in the soil and the moisture holding capacity was + 0·886**[1], a very high figure for this type of material. There could be no doubting the fact that a direct relationship existed. In the apple investigation, the correlation between size of tree and biennial bearing index was only + 0·049, which provided no evidence of any relationship. In such cases, a decision as to significance was comparatively easy. In other cases, however, it was not so easy.

It was obvious from field observation and from the correlations, that there were many cases of two or more interrelated factors affecting the same function. In such cases the partial correlation method was used to eliminate the effects of one or two factors at a time. For example, in the terminal shoot studies a correlation of + 0·853** was obtained between terminal diameter and terminal length, and + 0·558** between terminal diameter and annual trunk increase. The correlation between trunk increase and terminal length was + 0·380**. By the partial correlation procedure, the first two correlation figures became + 0·836** and + 0·487** respectively. This did not change the picture greatly. In other cases, however, the picture was quite definitely changed. For example, the correlation between soil pH and apple yield was + 0·267*, indicating a definite relationship between the two. Both of these were also related to the moisture holding capacity (correlations + 0·586** and + 0·410** respectively). When the effects of moisture-holding capacity were eliminated, the correlation between soil pH and yield was reduced to + 0·036. This indicated the possibility that the apparent effects of pH on yield may have been incidental to the more general effects of soil texture on yield. It illustrated one of the pitfalls encountered in interpreting correlations.

In the apple investigation, too many factors were measured to allow elimination by the partial correlation procedure. At the same time, it was considered necessary to eliminate some of them statistically in order to study the others. Three factors were selected that showed close relationships with yield, these being size of tree, terminal length, and biennial bearing index. The regression of yield on size of tree was calculated, and all yields were individually adjusted to a standard size of tree. The regression of this adjusted yield on terminal length was then calculated and the procedure repeated. The same was then done with the biennial bearing index. The other factors were then correlated with these triply-adjusted yields, and in some cases also with the unadjusted, the singly-adjusted and the doubly-adjusted yields. This procedure revealed several relationships that could not otherwise have readily been discovered. With so many adjustments, however, the interaction of the factors sometimes made interpretation of the results difficult. It became obvious as the investigation progressed that only those correlations with high significance could be accepted as being valid. It also became obvious that in an investigation of this kind the more factors that could be eliminated in the initial selection of material, the more reliable would be those results obtained from the factors recorded.

[1] Two asterisks following a coefficient of correlation indicate odds greater than 99:1 (highly significant). One asterisk represents odds between 99:1 and 19:1 (significant). And no asterisk represents odds below 19:1 (non-significant).

The question arises as to whether factors other than those recorded and used for adjustment purposes might not reduce the tree yields to such an extent as to mask the effects of the factors recorded. This no doubt had some effect on the factors of minor importance; that is, those which had a lesser effect on the function, as, for example, the P or K content of the shoots in the apple investigation. With factors of major importance it reduced the coefficients of correlation considerably but did not entirely mask the relationship. In the case of the effects of soil texture on tree yield (see Figure 1) it is obvious that the lower yields were reduced by factors other than soil texture. The upper yields across the top of the diagram were probably reduced little, if at all, and appear to represent reasonably well the trend in these selected plots. The trend for the whole distribution, however, is not so greatly different from that of the higher yielding plots, and the coefficient of correlation (+ 0·410**) is still considered to be "highly significant". The same holds true with the correlation between the biennial bearing index and tree yield (see Figure 2).

Several of the correlations were deceptive. Results that appeared at first to be clear-cut were found, on further investigation, to be misleading. For example, in the tree vigour studies a correlation of + 0·437** was ob-obtained between increase in trunk circumference and terminal length in 1934; and one of + 0·526** was obtained in 1935. It appeared from this that not only did the more vigorous trees grow more in both these ways, over a period of years, than did the less vigorous trees, but they must also have been affected in similar manner by biennial bearing. This latter, however, did not prove to be the case, as was shown by further studies. In order to determine the effects of biennial bearing on annual measurements, it was found necessary to eliminate the effects of general differences in tree vigour. This was accomplished by determining the 1934/1935 ratios for both increase in trunk circumference and terminal length. When these ratios were correlated with one another the coefficient was − 0·417**. This opposite effect of biennial bearing on these two factors has been found to hold true in all subsequent investigations.

Another example of a deceptive relationship was that obtained between the K content of the soil and yield. A coefficient of + 0·374** was obtained, indicating that higher yields were, on the average, obtained where the soils contained higher percentages of available K. As with the case of soil pH noted above, however, both the K content and the yield were closely correlated with the soil texture as represented by the moisture-holding capacity. When the effects of moisture-holding capacity were eliminated, the partial correlation obtained was only + 0·032. It might be concluded from this that there actually was no relationship between K content of soil and yield. Even this conclusion, however, might not be justified, as there remains the possibility that the beneficial effects of heavier soils on yield might have been due in part to their higher contents of available K. This illustrates well the confusion that may arise in interpreting results.

A correlation is, of course, merely a mathematical expression of a relationship between two sets of data. Either one of these may be a factor and the other a function; or both may be functions affected in similar or in opposite manner by a common set of factors. For example, a cor-

relation of + 0·410** between moisture-holding capacity of the soil and tree yield merely indicates that from the statistical viewpoint, there is a highly significant positive relationship between the two sets of data. It remains for the operator to suggest which affects which, if either, or whether the relationship is merely coincidental. In this case the moisture-holding capacity of the soil was considered to be the factor, and yield the function. It could not be concluded, however, that the moisture-holding capacity had a direct positive effect on yield. All that could be concluded was that the two were closely related, and that possibly soil moisture, colloid content, nutrient content, and indeed all those factors associated with soil texture, were instrumental in affecting the yield. In the same manner, caution had to be exercised in interpreting many of the other correlations. Another example was the very high correlation (− 0·914**) between the sand content of the soil and its wilting coefficient. It could be concluded that the sand in the soil had an inverse or negative effect on the wilting coefficient; but it would appear to be more correct to say that the silt + clay content, which supplements the sand content, has a direct or positive effect on the wilting coefficient.

In this discussion of some of the problems encountered, not only a number of the difficulties, but also some of the methods used in overcoming these difficulties have been reviewed. All of the major difficulties cannot be overcome under field conditions; but in spite of this it may be possible to glean sufficient information from a survey to make the investigation well worth-while.

FINDINGS OF VALUE

The above discussion of the many difficulties encountered in these investigations could well leave the impression that the investigations were not worth-while. In order to balance the picture somewhat, therefore, the major findings will be briefly reviewed.

Tree Vigour Studies

High positive correlations were obtained between terminal length, terminal diameter and increase in trunk circumference. The diameter near the tip of the terminal was found to be better than that at the base. As the trees increased in size, their vigour tended to decrease, although this was not considered to be a fundamental relationship, as it depended largely on the amount of nitrogen applied. With trees bearing biennially, the year of heavy crop was the year of smaller increase in trunk circumference but longer terminals. These findings were very valuable in developing simple methods of measuring the vigour of mature bearing trees.

Soil Moisture Studies

In the first investigation, correlations were obtained between the silt, clay, and colloid contents of the soil and the settling volume on the one hand, and field capacity, wilting coefficient and available moisture content of the soil on the other hand. Straight regression lines were calculated for use in determining the three moisture contents from mechanical analysis or settling volume measurements. The errors involved in making such determinations were also calculated. The same types of correlation were

obtained in a second investigation, in which the moisture equivalents were also determined. Curved regression lines were calculated this time, and the errors involved in using them were likewise determined. The most reliable laboratory methods for determining the three pertinent moisture contents of the soil were presented. These results have been of great value in subsequent field studies involving soil moisture, and in the classification of soils on the basis of their moisture-holding capacity.

Apple Yield Studies

The findings noted above on tree vigour were confirmed. Close positive correlations were obtained over a period of years between increase in trunk circumference, terminal length, and terminal diameter. With biennially bearing trees the trunks grew more and the terminals were shorter but thicker in the "off" year than in the "on" year. High positive correlations were obtained over a period of years between tree size and terminal length on the one hand, and total yield and yield of high quality fruit ("profitable yield") on the other hand. A still higher negative correlation was obtained between the degree of biennial bearing and yield. An increase in the degree of biennial bearing was accompanied by a greater reduction in yield than was found by variations in any other single factor studied in this investigation. The optimum degree of biennial bearing was found to be zero, and the optimum annual terminal growth 25 centimetres.

The heavier soils were found to have higher pH values than the lighter soils, also higher contents of organic matter, lime, and available calcium, potassium and magnesium. There was no clear relationship between soil texture and P content. The heavier the soil, the more vigorous were the trees and the higher was their yield; just what were the causes of these relationships was not determined. Higher yields were also obtained with higher pH values and higher contents of organic matter, K, Ca and Mg in the soil, though it was questionable whether any of these factors had any actual measurable effect on tree yield. A negative relationship was found between soil pH and P content, and positive relationships between soil pH and contents of K, Ca and Mg. No clear-cut relationship was found between root distribution and tree growth or yield.

By analysis of the terminal shoots and leaves, it was found that in the "on" year the N content was lower and the P and K contents were higher than in the "off" year. This finding was important in affecting the method of selecting samples for tissue analysis. Positive correlations were obtained between the available P and K contents of the soil and the P and K contents of the shoots; between the N and P contents of the shoots; between N content of shoots and terminal length, and between N content of shoots and yield. Correlations between P or K content and yield were not significant.

One of the main purposes of this investigation was to find out if any major nutrients were deficient in any part of the Okanagan Valley. Nitrogen was the only element studied that was found to be definitely deficient in any of the plots. If deficiencies of P, K, Ca or Mg occurred, it was not possible to establish these deficiencies definitely by this procedure. Possibly some deficiencies were present, but not in sufficient degree to affect tree growth and yield adversely; that is, adversely enough to produce statistically significant correlations between the nutrient contents of the soil or terminal

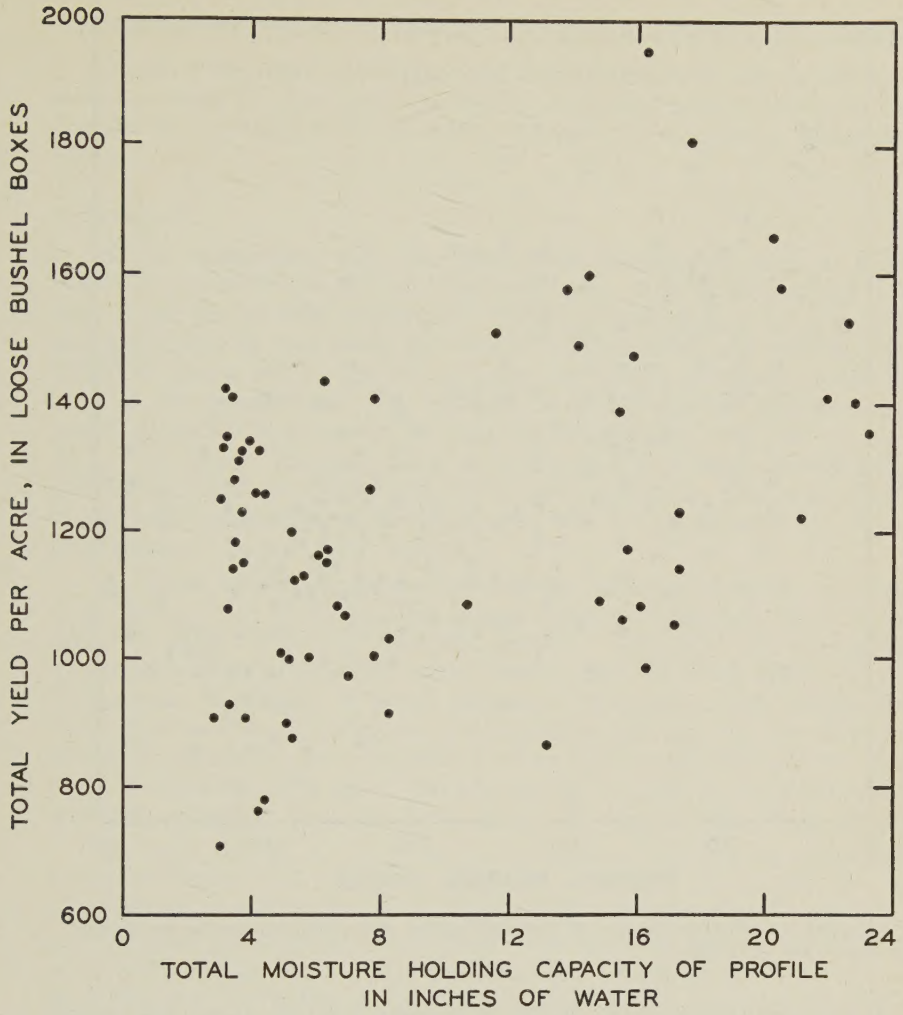

FIGURE 1.—Scatter diagram of total moisture holding capacity of profile charted against total yield per acre. $r = +0{\cdot}410$

shoot and tree growth or yield. It is also possible that definite deficiencies did occur, but that their presence was masked by factors which had a much stronger influence on growth and yield.

These investigations have served to indicate the value of measurement and statistical analysis as compared with observation only. For example, on the basis of observation alone, technical workers had disagreed as to whether or not terminal shoots grow longer in the "on" year than in the "off" year. The correlations obtained in these investigations have indicated quite definitely that they do grow longer in the "on" year. In some cases the results actually ran counter to prevailing opinion. For example, tree vigour was found to have little effect on the degree of biennial bearing. This was apparently due to the strong effects of meteorological conditions. Another surprising result was the lack of correlation between the organic matter content of the soil and tree yield.

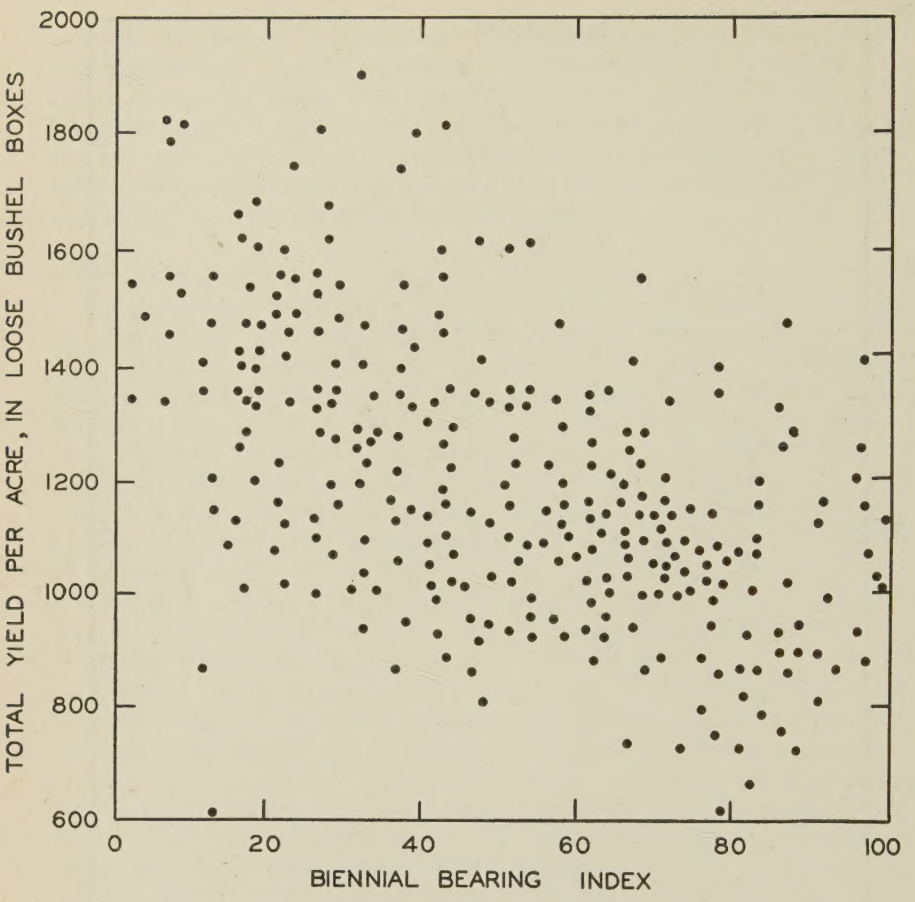

FIGURE 2. Scatter diagram of biennial bearing index charted against total yield per acre. $r = -0.526$

Where there are so many factors affecting a function, it has been found very difficult to assess the proper relationships by observation alone. As an example, the correlation obtained between soil texture (as represented by the moisture-holding capacity) and tree yield may be cited. Many cases were found where it was obvious that trees in sandy soil were giving higher yields than trees in nearby heavy soils; yet the coefficients of correlation and the distribution charts showed clearly that on the average the reverse held true. This is illustrated in Figure 1, where moisture-holding capacity is charted against yield. Although in any one type of soil there was a wide range of tree yields, the general trend, for the average yield to increase as the soil became heavier, was apparent. Similar difficulties had been encountered in assessing the effects of biennial bearing on tree yield. As will be seen from Figure 2, large variations in yield occurred at any one degree of biennial bearing; yet there was a general trend for the yield to decrease as biennial bearing increased.

The large amount of valuable information obtained from these investigations indicates that the work was well worth-while.

SOME ADVANTAGES AND DISADVANTAGES OF THE SURVEY MOTHOD

Most of the main advantages and disadvantages of the survey method as encountered in these investigations have already been noted in the above discussion. It appears worth-while, however, to summarize them at this point.

Advantages

1. In comparison with the more exact procedures, such as growing plants in a greenhouse, the field methods have a distinct advantage in that they make use of field conditions. Field variability in soil type, climate, size and shape of tree could not well be duplicated in the greenhouse. It would of course not be feasible to study the factors affecting mature apple trees in the greenhouse. For example, it would not be feasible to study under glass the interaction of distance of planting and size of mature McIntosh trees. In some cases, it is doubtful if findings disclosed in the greenhouse could be applied directly to field conditions. One reason for this is the wide interaction of factors in the field compared with those in the greenhouse.

2. Using the survey method of research, it is not necessary to plan the experiment years ahead of time, plant the crop, and wait for it to reach maturity before obtaining the required data. This is of course of greatest importance with plants that take several years to reach maturity, as do fruit trees. Moreover, it is not necessary to set up a wide range of soil, nutritional or other conditions or treatments and wait for the differential effects to appear in plant behaviour. The fact is that the operator has at hand an outdoor laboratory, already set up for him in the grower-owned orchards or fields. The material is there, waiting for him to use it.

3. Even though a survey for the purpose of discovering relationships between factors and functions may not represent adequately the soils, plant materials or cultural operations over the area concerned, it should still provide good information about them. The operator gains a clearer picture of the status of the crop under consideration. Problems are discovered that show the need for further work; and suitable material is located on which to conduct this further work. Following the apple investigation, for example, it was possible to select orchards low in P and K on which to lay out fertilizer plots.

Disadvantages

1. The greatest disadvantage in the survey method is the multitude of factors with which the operator must contend. True, some of them can be eliminated and the range of others lessened in the selection of material; but there remains too large a group of factors for the operator to be able to analyse adequately all their individual effects and interactions. By the intelligent use of statistical procedures, it is usually possible to gain a clear picture of the major relationships involved. The minor relationships, however, may be so masked by the major ones that their discovery and interpretation are very difficult.

2. It is necessary to select more material for use in the investigational work than with plot work or greenhouse work. In order to obtain the

same records, therefore, it becomes necessary for the operator to spend more time at it. In addition, the time and expense involved are increased by the extra travel required.

3. The operator may find it difficult to control those factors receiving special study. For example, the grower may change his fertilizing, pruning, irrigating or spraying program during the process of the investigation. The operator of course has no control of the weather.

Purpose of a Research Survey

A research-type of survey can serve several good purposes. In the first place, it can reveal which factors are of greatest importance in affecting the functions, and which are of less importance. It can reveal those relationships existing among the major factors, and between these factors and the functions. It can reveal problems that need more exact study, and supply the materials with which to conduct further studies. To some extent it can be likened to a voyage of discovery prior to settlement of new lands.

The research type of survey cannot be expected to reveal exact relationships among the lesser factors, or between these factors and the functions. In order to establish effects of minor factors on yield or some other function, it is usually necessary to eliminate the effects of major factors in some way, such as can be done under strictly controlled experimental conditions. Nor can the survey method be expected to reveal information of a more purely fundamental nature, such as the function of an element in the plant. Although it can bring major relationships to light, it does not necessarily explain them. If any information of a strictly fundamental nature is obtained, it can be accepted by the investigator with pleased surprise.

The apple investigation did not indicate great promise for use of the survey method to determine the critical nutritional levels of soils or plants. Once standards of nutrient levels in the soil or plant tissues have been established, then the nutritional status throughout the area concerned can be determined by an ordinary survey involving soil and tissue analyses. In order to establish these levels in the first place, however, greenhouse, injection or field-plot studies hold greater promise than does the survey method. It is true that when a serious deficiency of an element occurs, a good correlation may be obtained between this element and plant performance; but usually other methods are better adapted to establishing this deficiency.

SUMMARY

Investigations of the survey type, previously reported by the author and his co-workers, are used as a basis for a discussion on the use of the survey method in horticultural research. Chief among these investigations were field studies of apple tree vigour, field and laboratory studies of soil moisture, and field and laboratory studies of factors affecting the yield of apple trees.

The major problem encountered in these studies was field variability, caused chiefly by the large number of factors concerned. Some of the factors were eliminated in part by selective choice of material, others by measurement and subsequent statistical treatment. Various procedures were used to glean from the data the various cause-and-effect relationships.

Difficulties were encountered, however, in interpreting the results obtained. In spite of all the difficulties encountered, the investigations were considered to be well worth-while.

The major advantages of the field survey method are: (1) that the results obtained are applicable to field conditions, (2) that the material is already waiting to be used, and (3) that the need for more exact work is revealed and the material necessary for this work is discovered. The chief disadvantages are: (1) that the multitude of factors makes interpretation difficult, (2) that on this account larger samples have to be measured and recorded, and (3) that it is difficult to maintain the factors at steady values during the course of the investigation.

It is concluded that the research-type of survey can serve several good purposes, such as revealing the major relationships between factors and functions. It cannot be expected to reveal minor relationships, nor relationships of a strictly fundamental nature. It does not show special promise for determining the critical values of nutrient elements in the soil or plant tissue.

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EXPERIMENTS ON THE SELF-SELECTION OF A DIET BY FOXES[1]

L. M. Bezeau[2] and T. B. Gallant[3]

Dominion Experimental Fox Ranch, Summerside, P.E.I.

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INTRODUCTION

During experiments with dehydrated whole egg powder, at the Dominion Experimental Fox Ranch, it was noted that biotin-deficient foxes would consume brewers' dried yeast per se, which is a good source of biotin. It also has been observed that foxes housed in pens raised off the ground would eat fresh grass when this was provided, even though they were being fed an apparently well balanced diet. These facts suggested that the fox instinctively sought to balance its own ration when provided with the necessary foodstuffs. "Self-selection" or "free choice" experiments were inaugurated in order to study this more completely.

REVIEW OF THE LITERATURE

One of the earliest reports on self-selection feeding was by Evvard (6) who worked with pigs and concluded that the appetite of the pig was a reliable indication of bodily needs. However, Nevens (9) found that cows do not select feeds in the proper amounts or the proper proportions to meet their nutrient requirements. Osborne and Mendel (10) provided rats with two diets, one nutritionally superior to the other. When confronted with these two experimental diets, the rats showed a definite preference for the superior diet.

A number of workers (1, 3, 11, 12, 15, 17, 18, 27) have reported abnormal food preferences in both laboratory animals and humans, under abnormal anatomical or physiological conditions, which indicated that the species under observation was trying to satisfy a nutritional need. Richter and co-workers (13, 16) found that rats have the ability to select a balanced ration during growth, pregnancy, and lactation. Scott and co-workers (22) observed a variation in preference for certain nutrients between old and young rats and between pregnant and non-pregnant rats. They also noted (19) that, aside from salts and calories, the appetites of rats showed no apparent relation to physiologic or nutritional needs, and that rats relish a change in the carbohydrate portion of their ration (23).

Kon (8) reports that rats on a self-selection diet consumed a ration that contained only 6.5 per cent protein. These rats did not grow as well as the control animals receiving a mixed ration containing 20 per cent protein. Carlson and Hoelzel (2), using a vegetarian self-selection diet, found that rats were generally fertile on such a diet but raised less than 25 per cent of their offspring. The growth of the progeny also was subnormal and severe rickets commonly developed. Some workers in this field have not provided the animals with all of the required nutrients. The vitamin aspect particularly has been neglected. For instance Dove

[1] Contribution from Experimental Farms Service, Dominion Department of Agriculture.
[2] Assistant in Nutrition; present address, Experimental Farm, Lethbridge, Alta.
[3] Technician.

(5) provided his rats with cornmeal, wheat bran, oats, skimmilk powder, fishmeal, bonemeal and oyster shell, which undoubtedly would be low in vitamins A and D.

Deuell and Movitt (4) found that rats prefer butter to hydrogenated vegetable oils, while Scott and Verney (25) report the reverse to be true, which would indicate that rats, as a species, do not have clear-cut likes and dislikes in their feeding habits.

No reports, to the authors' knowledge, have appeared in the literature regarding the ability of the fox to select an adequate diet.

PROCEDURE

Two separate experiments were carried out, using slightly different procedures. In the first experiment 28 feeds that are commonly found in fox rations were used, while in the second experiment the number of feeds was limited to seven. These seven feeds contained all of the essential food nutrients known to be required by foxes.

Experiment No. 1

Three trials were carried out in this experiment. In the first trial, six 8-week-old weanling pups were used (three males—7B, 8B, and 18B, and three females—1B, 2B, and 3B). In the second trial, six 20-week-old or half-grown pups, which were the same animals as used in the first trial, were placed on the self-selection diet. In the third trial, four adult foxes (7A, 45A, 131A, and 65Z) were used.

The following 28 feeds were placed before the foxes in individual pans: alfalfa meal, cooked barley, raw barley, dried beet pulp, blood meal, commercial steamed bonemeal, fortified cod liver oil (1800A-800D), dehydrated whole egg powder, fresh frozen fish (Novascot Fishblox), fishmeal, ground flaxseed, fresh grass clippings, ground cabbage (when grass was out of season), ground horsemeat, ground limestone, linseed meal, ground beef liver, meat meal, molasses, cooked oats, raw oats, iodized salt, skimmilk powder, ground beef tripe, wheat bran, wheat germ, cooked wheat, raw wheat and brewers' dried yeast.

In preliminary trials it was found that foxes preferred cereal grains in the dry, rather than in the moist, state and that they showed a preference for grains ground through a 1/16 inch screen rather than a 1/8 inch or 1/32 inch screen. It also was observed that grass clippings were eaten more readily than ground grass. Using the findings from these preliminary trials, the barley, oats, wheat, and beet pulp were ground through a 1/16 inch screen and were fed dry. The cooked grains were autoclaved for 15 minutes at 15 lb. pressure. The feed pans were placed in wall brackets about eight inches off the floor in a large room. The room was so situated that the foxes could be observed without the observer being seen. Each day the foxes were placed in the room for approximately 30 minutes or until they finished eating. The fox pups were weighed once a week. The feed consumed was recorded each day and at the end of each week the percentage composition of the ration was calculated in order to note any changes in food preference as growth and the season progressed.

TABLE 1.—WEEKLY PERCENTAGE COMPOSITION OF RATIONS CONSUMED BY FOXES ON SELF-SELECTION RATIONS

	Pups						Half-grown pups				Adults			
	1st week	2nd week	3rd week	4th week	5th week	6th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
Alfalfa meal	—	—	—	—	0.01	—	—	—	—	—	—	—	—	—
Barley, cooked	—	0.01	0.03	—	0.01	—	—	0.01	0.01	0.03	0.02	—	—	—
Barley, raw	—	0.03	0.01	0.02	0.03	—	0.01	0.01	0.01	0.02	0.05	0.02	0.02	—
Beet pulp	0.01	0.03	0.03	0.01	—	—	—	—	—	—	—	—	0.02	—
Blood meal	0.01	0.01	0.03	0.01	0.04	0.04	0.01	—	—	—	0.02	—	—	—
Bonemeal	0.10	0.05	0.08	—	0.01	0.01	0.03	—	0.01	—	—	—	—	—
Cod liver oil	0.71	0.04	0.21	0.09	0.03	0.01	0.02	0.06	0.14	0.01	0.91	0.04	0.11	0.09
Egg powder, whole	—	0.07	0.01	0.02	0.07	0.10	0.03	0.01	0.04	—	0.07	—	0.09	0.06
Fish, fresh (fishblox)	0.19	0.05	0.16	0.54	0.09	0.12	0.05	0.11	0.04	0.12	0.29	—	0.24	0.09
Fishmeal	0.02	0.02	0.02	0.01	0.03	—	0.01	0.02	0.01	0.02	0.02	0.05	—	—
Flaxseed, ground	0.04	—	—	0.02	0.01	—	—	—	—	—	0.02	—	—	—
Grass, fresh	0.02	0.09	0.13	0.13	0.08	0.07	0.04	0.11	0.07	0.02	0.10*	—	—	—
Horsemeat	49.28	85.90	80.35	71.37	77.70	76.20	74.50	80.50	90.75	88.92	80.30	78.94	69.10	67.00
Limestone, ground	—	0.07	0.24	0.11	0.11	0.12	0.02	0.01	0.01	0.04	0.05	—	—	—
Linseed, meal	—	0.01	0.02	0.01	0.01	—	0.01	0.01	—	—	—	—	—	—
Liver, beef	17.76	8.01	13.20	24.60	17.70	20.15	16.20	12.30	5.60	7.49	4.36	6.54	5.95	0.47
Meatmeal	—	0.07	0.06	0.04	0.04	0.04	0.03	0.02	—	0.03	0.02	—	—	0.03
Molasses	—	—	0.06	0.04	0.08	0.07	0.55	0.38	0.39	0.06	2.01	1.22	0.29	0.22
Oats, cooked	—	0.02	0.02	—	0.02	—	0.01	0.03	0.01	—	0.02	—	—	—
Oats, raw	—	0.01	0.02	0.01	0.02	0.01	0.01	0.04	0.01	0.02	—	—	0.02	—
Salt, iodized	0.04	0.02	0.03	0.01	0.04	—	0.01	0.01	—	0.01	—	0.02	—	—
Skimmilk powder	0.17	0.07	0.13	0.09	0.04	0.02	0.09	0.02	—	—	0.05	0.05	0.04	—
Tripe, beef	31.57	5.31	5.00	2.85	3.70	3.02	8.28	6.30	2.85	3.14	11.60	13.10	24.12	31.95
Wheat bran	—	—	0.02	0.01	0.02	—	0.01	0.01	—	0.01	0.05	0.02	—	—
Wheat germ	—	0.03	0.07	—	0.02	—	0.01	0.01	0.03	0.04	0.02	—	—	0.09
Wheat, cooked	—	0.04	0.02	—	0.02	0.01	0.02	0.02	0.01	—	0.02	—	—	—
Wheat, raw	—	0.01	0.01	—	0.03	—	0.01	0.01	0.01	0.01	—	—	—	—
Yeast, brewers' dried	0.08	0.03	0.04	0.01	0.04	0.01	0.04	—	—	0.01	—	—	—	—

* Ground cabbage fed in place of fresh grass in adult feeding trial.

Experiment No. 2

Harris *et al.* (7) found that when a large number of feeds were placed before rats, they became confused and rarely selected the nutrients that would produce the most beneficial results. In order to determine if this was the reason why the foxes in the first experiment consistently had chosen an unbalanced ration, six pups were placed on a self-selection diet containing the following seven feeds:

(1) Casein as a source of protein.
(2) Ground beef suet as a source of fat.
(3) Ground beet pulp as a source of fibre.
(4) Fortified cod liver oil for vitamins A and D.
(5) Brewers' dried yeast for the vitamin B complex.
(6) Minerals (4 bonemeal: 1 salt).
(7) Dehydrated potatoes as a source of carbohydrates.

The procedure, other than the number of feeds used, was identical with that followed in the first experiment and the pups were maintained on this ration for three weeks.

RESULTS AND DISCUSSION

Experiment No. 1

(1) At the end of five weeks on the self-selection diet the weanling fox pups 1B and 7B were showing symptoms of rickets and one week later the hind legs of 7B were almost useless. During this trial the six foxes had consumed a ration containing only 0.18 per cent cod liver oil as is shown in Table 1, instead of the $1\frac{1}{2}$ to 3 per cent recommended by some workers. They also showed a definite preference for ground limestone rather than steamed bonemeal. Fresh meat (horsemeat, liver, and tripe) made up 98.9 per cent of the total feed consumption during the six-week period. The average daily feed consumption per fox for the six weeks was 242 grams of feed while normal consumption for a growing pup is 300 grams and more.

(2) The six foxes from the first trial were placed on a cod liver oil supplemented ration and two weeks later 1B and 7B were again apparently quite normal. After six weeks on this ration the same pups, now approximately 20 weeks of age (half-grown), were again placed on the self-selection diet. At the end of four weeks 7B again showed definite symptoms of rickets and as none of the other foxes was consuming what was considered a balanced ration the experiment was discontinued. It is significant that 7B, the first fox to become rachitic, grew more rapidly than any other fox in the experiment as is shown in Table 2. In fact the growth curve was almost normal for a fox of that age. The cod liver oil consumed during this period was 0.06 per cent of the total ration. The fresh meat (horsemeat, liver, and tripe) constituted 99.2 per cent of the total ration consumed and the average daily consumption per fox was 274 grams of feed for the four-week period.

(3) The four adult foxes which were placed on the self-selection diet persisted in consuming a ration which was considered to be nutritionally unbalanced, so the trial was discontinued at the end of four weeks. The ration consumed during the four-week period averaged 98.4 per cent fresh

meat (horsemeat, liver, and tripe) and the average daily consumption per fox was 222 grams of feed. Normally, adult foxes consume about 280 grams of feed per day. It is of interest to note that the adult foxes consumed a higher per cent of tripe but a lower per cent of horsemeat and liver than the pup foxes in the first trials.

TABLE 2.—WEEKLY BODY WEIGHTS OF FOX PUPS ON SELF-SELECTION DIETS

Age in weeks	Fox numbers					
	1B lb.-oz.	2B lb.-oz.	3B lb.-oz.	7B lb.-oz.	8B lb.-oz.	18B lb.-oz.
8	4–00	4–01	4–04	3–08	3–10	3–10
9	3–14	3–12	4–01	3–12	3–12	3–14
10	4–00	4–02	4–05	4–01	4–02	4–04
11	4–14	4–12	5–04	5–02	5–00	4–03
12	5–03	4–15	5–08	5–06	5–06	4–09
13	5–04	5–06	6–00	5–10	5–08	4–14
14	5–00	5–11	6–04	5–14	5–12	5–10
20	7–14	8–01	9–03	9–15	8–08	8–08
21	7–02	7–14	8–12	10–08	8–12	8–10
22	7–08	8–06	9–04	11–00	9–05	9–00
23	7–12	8–06	9–08	11–04	9–12	9–04
24	7–08	8–08	9–06	11–08	9–14	9–06

Experiment No. 2

At the end of three weeks the pups on the self-selection diet, containing only seven feeds, had lost an average of 10 ounces in body weight which was at a period in their life when they normally would be gaining 8 to 10 ounces a week. Because of the severe losses in body weight the experiment was discontinued at the end of the three-week period. The average daily consumption of feed for this three weeks was only 20 grams. The percentage composition of the ration consumed was as follows:

	Per cent
Suet	96.50
Cod liver oil	2.72
Brewers' yeast	0.36
Beet pulp	0.18
Minerals	0.14
Casein	0.05
Potatoes	0.05

It will be noted that the pups, during this test, consumed considerably more cod liver oil than was consumed by the pups in Experiment 1.

SUMMARY AND CONCLUSIONS

Six weanling pups, six half-grown pups, and four adult foxes were placed on a self-selection diet with 28 feeds from which to choose. None of the groups selected a nutritionally balanced diet since the fresh meat made up 98.8 per cent of the ration consumed in all groups. In both pup

groups a rachitic condition developed even though cod liver oil, bonemeal, and limestone were available to them. The results indicate that neither weanling pups, half-grown pups, nor adult foxes are able to select, from this large assortment of feeds, those which are essential to their growth and physiological well-being.

In a second experiment six pups were placed on a self-selection diet in which there were only seven feeds from which to choose. The results of this experiment showed that, even when fox pups have only a limited number of feeds from which to choose, they still are unable to select a nutritionally balanced ration.

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PERSIAN DARNEL IN CANADA[1]

W. G. DORE[2]

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During the past two decades an annual weed, locally known as "darnel", has become well established at numerous widely-separated points in the Prairie Provinces. While not yet abundant enough to cause serious economic losses to grain producers, it indeed may come to do so in the near future. It seems appropriate to put on record now some information of a botanical nature that has recently been gathered about the grass.

HISTORY OF NOMENCLATURE

Much confusion has existed in Canada as to the correct botanical name of this plant. Being an annual and resembling somewhat the well-known darnel of Europe, it was first called *Lolium temulentum* L. A specimen from wheat fields in the vicinity of Saskatoon sent to A. S. Hitchcock in Washington in 1925 by W. P. Fraser was identified more particularly as *L. temulentum* var. *macrochaeton* A. Br., the variety with long awns usually considered typical of that species. From subsequent correspondence and from additional specimens received at Ottawa from W. P. Fraser, it was apparent that this identification was not wholly acceptable to him. Since the exact identity remained in question, this varietal combination continued in use (6).

With the appearance of Rydberg's "Flora" in 1932 and the reference therein to an awned variety of *Lolium rigidum* as "the only form represented, with an awn 7-12 mm. long. Wheat fields: N.D., introduced from the Old World", the new combination name of *L. rigidum* Gaud., var. *Duethiei* Hook. was soon taken up for the weed introduced to the grain fields in Saskatchewan. Soon afterwards, Hitchcock's "Manual of the Grasses of the United States" (8) referred simply to *L. rigidum* as "annual, foliage blue-green, spikes rather stiff; otherwise like *L. multiflorum*—Wheat fields, North Dakota (Milton, Calio); Europe". Both locations in North Dakota mentioned by Hitchcock are within 30 miles of the Canadian border and since the brief description seemed sufficient for general reference, the bare specific name became widely used in agricultural literature—despite the fact that the plants are not particularly blue-green when fresh and the spikes not particularly stiff, at least not nearly so stiff and rigid as in the plants that Gaudin had in mind when he proposed the name *L. rigidum*. Dr. Malte, in annotating a specimen, pointed out that Gaudin's original description (5) stated that the spikelets were awnless, but left it at that. Although Professor Fraser used *L. rigidum* in his Saskatchewan list (4) he was apparently not fully satisfied with it, since he appended, "exact species has not been determined".

IDENTIFICATION OF DARNEL

In attempting to arrive at an acceptable identification of the darnel, it was apparent that recourse to original descriptions and authentic specimens had to be taken. There was no doubt that the grass was a species of

[1] Contribution No. 998 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Botanist.

Lolium. The sessile spikelets, one at each node, inserted dorsally on the rachis with the first glume entirely lacking (except in the terminal spikelet), places it distinctly within this genus.

Lolium is not a native American genus. Most of the species in the New World were introduced from Europe in times of early settlement. A search of European floras, however, yields no description exactly applicable to the weed now passing as *L. rigidum* in North America. Some of its distinctions from the European species with which it has been confused may be mentioned. It differs from *L. temulentum* var. *macrochaeton* in its more slender stature, lanceolate (rather than elliptical) lemmas, in glumes shorter (rather than longer) than their spikelets, and palets longer (rather than shorter) than their lemmas. From *L. temulentum* var. *leptochaeton* it differs, in addition, by the presence of awns. Both varieties of *L. temulentum* have been introduced to Canada on numerous occasions but seem not to have become naturalized. It differs from the true *L. rigidum* of Gaudin in its more slender rachis, its firmer and more coriaceous lemmas and presence of awns. *L. rigidum* has recently been introduced into Australia and, under the trade name of Wimmera Rye-grass has gained considerable importance as a forage species. By some workers there, it is rated as the most useful and most palatable grass for range pastures in the drier and often saline areas in Australia (3, 12). The slender, almost leafless and worthless weed of our western grain fields could not possibly pass under the same scientific name without creating much suspicion. *L. multiflorum* is a short-lived perennial with short glumes and herbaceous lemmas, frequent in new lawn and meadow seedings, and readily distinguishable from our darnel.

The awned variety of *L. rigidum*, cited by Rydberg (11) as var. *Duethiei* Hook., is an Asiatic variety, first described by Hackel in J. D. Hooker's, "Flora of British India" (9) in 1896. In this work it bears the original spelling of var. *Duthiei* and authorship correctly ascribed to Hackel. The description was based on specimens collected by J. F. Duthie in Kashmir, now preserved in the herbarium of the Royal Botanic Garden, Kew, England. A duplicate specimen of Duthie's type in the United States National Herbarium has been examined and found to be distinctly different from Canadian darnel. Specimens from Milton, North Dakota, which probably provide the basis for Rydberg's and Hitchcock's reports of *L. rigidum*, likewise do not compare well with the type material. It is concluded that *L. rigidum* or its variety *Duthiei* does not occur in North America. Details of the spikes of the species mentioned in the above two paragraphs are shown in Plate I.

IDENTITY AND DESCRIPTION OF *Lolium persicum*

On consultation of modern Russian floras (7, 10), the Canadian plants key out directly to *L. persicum* Boiss. & Hoh., a species ranging from the Caucasus through northern Iran, to the mountainous parts of Turkestan, Syr-Darya, Pamir, and Tien Shan in middle Asia. The type specimen was collected in the district of Derbent, Persia (Iran), by T. Kotschy in 1843 and is preserved in the herbarium at Geneva, Switzerland.

PLATE 1. Spikes of annual species of *Lolium*. FIGURE 1. *L. rigidum* var. *Duthiei* from specimen of type material from Kashmir, preserved in U.S. National Herbarium. FIGURE 2. *L. persicum* from Russia, cultivated at Forage Division, Experimental Farm, Ottawa. FIGURE 3. *L. persicum* from Simpson, Saskatchewan. FIGURE 4. *L. temulentum* var. *macrochaeton*. FIGURE 5. *L. temulentum* var. *leptochaeton*. FIGURE 6. *L. multiflorum*. FIGURES 4, 5, and 6 from plants cultivated at Forage Division, Experimental Farm, Ottawa. All spikes magnified 1.6 times.

The original description by Boissier (2) is inadequate in some details, but it is clear that Nevski (10), when expanding on the original description, had in mind the same species as Boissier, and undoubtedly referred to the co-type specimen preserved at Leningrad. His full description, and also other specimens collected in the type locality in 1902 by J. Bornmüller, labelled by the collector as *L. persicum* and preserved at Washington, agree perfectly with Canadian and North Dakota material. There remains no doubt that the plants introduced to North America are of this species. Spikelets of this species from Russia and Canada are shown in Plate I (Figures 2 and 3).

The distinctive common name Persian darnel may be proposed for general use.

The following description based on Canadian material is designed to bring out the main diagnostic points:

Lolium persicum Boissier & Hohenhaker. Pl. Pers. bor. 1846. *L. rigidum* of American authors, not Gaudin.

Bright green *annual*, blue-green on drying, 15 to 60 cm. tall, freely branching from the lower nodes, the branch stems closely ascending and all terminating in inflorescences. Blades 2 to 6 mm. broad, rough on the margins and nerves of the upper surface, smooth beneath. Spike one-quarter to one-half the height of the stem, with *slender rachis*. Spikelets 5- to 7-flowered, 1.5 to 2.2 cm. long (exclusive of awns). *Glume three-quarters to full length of spikelet*, 1.0 to 1.8 cm. long, diverging from rachis at angle of 20° to 30°, indistinctly 5- to 7-nerved. Lemmas coriaceous, the lower one in the spikelet five times as long as broad, about 10 mm. (8 to 11 mm.) long and 1.5 to 2.0 mm. broad (not spread out), *with slender awn of a length* (0.8 to 1.2 cm. long) *equal to that of body of the lemma* and arising just below its tip. Palet equal to, but *generally surpassing its lemma in length* by 1 to 2 mm., with straight firm and hispid-ciliate keels gradually converging into a slender point and *exposed along the upper half of the lemma*. Caryopsis 6 mm. long, 1.5 mm. broad.

In Canada two forms are represented. In one form, the culms are coarsely scabrous beneath the spike; in the other, the culms are smooth. The former is typical of the species; the latter, however, represents an undescribed form. In the citations below these two forms will be listed separately and in chronological order of collection.

CITATION OF SPECIMENS

In the following list, herbaria are designated by the following abbreviations: A—University of Alberta, Edmonton; Can—National Herbarium of Canada, Ottawa; DAO—Division of Botany, Department of Agriculture, Ottawa; DAS—Laboratory of Plant Pathology, Dominion Department of Agriculture, Saskatoon; DASC—Range Experiment Station, Dominion Department of Agriculture, Swift Current, Sask.; DAScott—Experiment Station, Dominion Department of Agriculture, Scott, Sask.; DAW—Rust Research Laboratory, Dominion Department of Agriculture, Winnipeg, Man.; M—University of Manitoba, Winnipeg; OAC—Ontario Agricultural College, Guelph; S—University of Saskatchewan, Saskatoon; US—United States National Herbarium, Washington.

I. Specimens of the rough-culmed form typical of the species:

Ontario:

Mortimer Island, north shore of Lake Superior, Thunder Bay District, old camp clearing, *Hosie, Losee & Bannan 1298*, July 27, 1937 (Can.). Nipigon, railway gravel, *Groh 77*, July 10, 1939 (DAO). Guelph, three specimens, all probably from same infestation in yard of Veterinary College and collected by students; *L. M. Marshall*, July 12, 1946 (OAC), *S. J. W. Rickord*, July 16, 1946 (DAO), and *W. M. Stacey*, July, 1946 (OAC).

Manitoba:

Benito, *Murray*, August, 1934 (DAO). Winnipeg, grass garden, Manitoba Agricultural College, *T. Johnson*, July 10, 1935 (DAW). St. Norbert, roadside, *Groh*, July 9, 1935 (DAO). Domain, patches in grass field, *E. Johnson*, June 27, 1941 (DAO). Makaroff, *Van Drecht*, July, 1948 (M).

Saskatchewan:

Saskatoon, *Fraser*, June 17, 1923 (DAS). Saskatoon common in wheat fields, *Fraser*, August 13, 1925 (US). Langham, *Russell & Scott*, July 6, 1926 (DAS). Saskatoon, plots, *Fraser*, July, 1926 (S). Tisdale, *Laister*, August, 1926 (DAO). Saskatoon, weed in grain fields, *Fraser*, July 11, 1928 (DASC). Sutherland, *Fraser*, 1929 (S). Simpson, *Walker*, fall 1931 (DAO). Thirteen miles west of Simpson, *Groh & Walker*, June 21, 1932 (DAO). Langham, *Groh*, June 23, 1932 (DAO). Carnduff, *Groh*, June 27, 1932 (DAO). Hafford, wheat fields, *Shevkenek*, June 24, 1933 (DAScott). McKague, cultivated field, *Breitung*, July 6, 1936 (S). Swift Current, experimental plots, *Budd*, July 13, 1936 (DASC). Radville, low area, *Heinrichs*, July 4, 1938 (DASC). Senlac, cultivated grain fields, *Gould per Russell* S1399, June 23, 1944 (DAO).

Alberta:

Altario, grain fields, *Black*, received March, 1936 (DAO). McLaughlin, submitted by *Carpenter*, July 16, 1936 (A). Edmonton, R. R. track, C.N.R. yards, *Sexsmith & Moss 4297*, June 23, 1937 (A). Spirit River, 2 miles west in roadside ditch, *Moss 7492*, July 23, 1947 (DAO, A). Spirit River, one mile north in roadside ditch and field, *Moss 7493* (DAO, A). Spirit River, station yard, *Groh 3069a*, September 7, 1946 (DAO). Spirit River, *Shewchuk*, July 10, 1947 (DAO). Codesa, trace infestation believed introduced in 1947, *Shewchuk*, July 20, 1948 (DAO). Northmark, quite bad infestation believed introduced in 1943, *Shewchuk*, July 22, 1948 (DAO).

United States:

Fargo, North Dakota, grown from seeds received from Milton, N.D., *Stevens*, July 25, 1911 (US). Fargo, grown from seeds found in wheat from Milton, *Stevens*, July 7, 1919 (US). Fargo, grown in garden, seed from Cavalier Co., 1941, *Stevens 623*, July 13, 1942 (DAO). Madison, Wisconsin, grown in weed garden, *Stone*, August, 1922 (US).

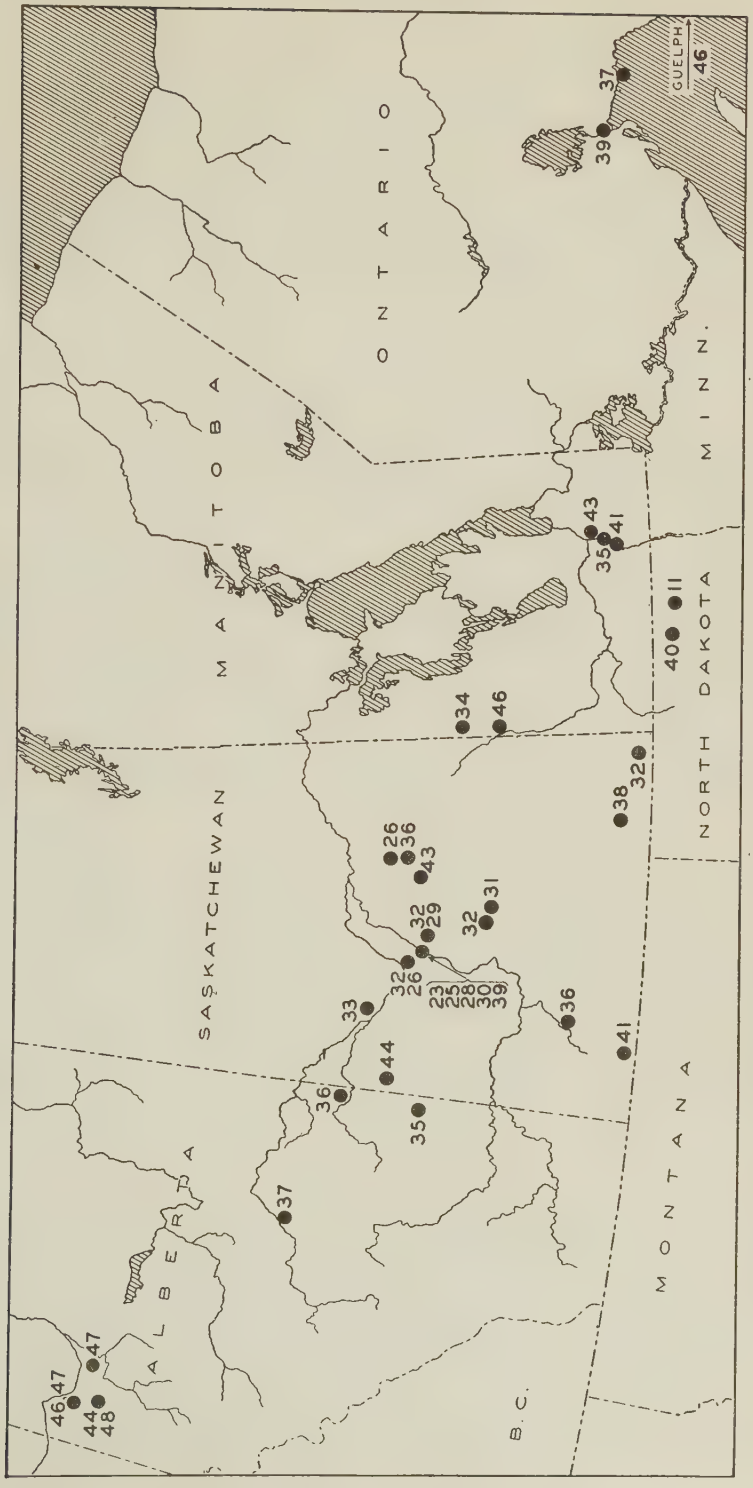

PLATE 2. Locations and dates of collection of the 38 specimens of *Lolium persicum* preserved in herbaria.

II. Specimens of the smooth-culmed form:

Manitoba:

North Kildonan, Winnipeg, farm, *Denike, 1789*, July, 1943 (DAO).

Saskatchewan:

Sutherland, *Fraser*, 1929 (S). Saskatoon, wheat fields, *Russell*, June 27, 1930 (DAS). Saskatoon, cultivated field, *Russell*, July 26, 1939 (DAO, DAS). Val Marie, irrigated field, *Campbell*, Aug. 1, 1941 (DASC). St. Gregor, cultivated field, *B. J. S. & Russell*, July 20, 1943 (DAS).

Alberta:

Northmark, Peace River, grain fields, *Rowe*, July, 1944 (DAO).

OCCURRENCE AND SPREAD

The present distribution as indicated by the herbarium specimens listed above is shown in the map (Plate 2). The figures by each dot refer to the year in the present century when the collections were made.

From these specimens, the history of the invasion of *L. persicum* reads somewhat as follows: The weed became established in Cavalier County in northeastern North Dakota some time prior to 1910; in that year, seeds were taken from grain samples and grown by Stevens at Fargo for identification purposes. The plants were reported as *L. temulentum* by Bergman in 1912 in his flora of the state (1). Stevens (13) reported these plants and others cultured from the same source in 1919 under the name of *L. rigidum* var. *Duthiei*. By 1930 it was considered a serious enough weed to be included in a revision of the North Dakota weed bulletin (14). In 1919 extensive distribution of durum wheat took place from Cavalier County.

The first specimen collected in Canada came from Saskatoon, where Professor Fraser detected it in 1923. In 1925 he noted it as "common in wheat fields, Saskatoon". In 1926 it was found at Langham and Tisdale, west and east of Saskatoon. In the "thirties" it appeared at several other points in central Saskatchewan and had spread as far as Carnduff and Radville in the southeastern corner, Swift Current in the southwest, and eastward across the border to Benito, and St. Norbert (near Winnipeg), Manitoba. The spread also occurred westward into Alberta, first near the border at Altario and McLaughlin, then at Edmonton. In 1937 and 1939, respectively, it had reached Mortimer Island and Nipigon on the north shore of Lake Superior in Ontario.

The weed got into the Peace River District of Alberta about 1943 and as far east as Guelph in 1946 (see below). C. E. Hubbard, grass specialist at the Royal Botanic Garden, Kew, who kindly verified the identity of Canadian specimens, writes that "only last year (1947) it turned up on refuse heaps around flour mills at Tewkesbury, Gloucestershire, England, where the occurrence of an Asiatic species was hard to explain since most of the grain coming into the country for milling came from Canada".

The present status of the weed may be gathered from information provided by agricultural workers in their respective areas. In North Dakota, it grows in various parts of the State, including the western

counties (O. A. Stevens). In central Saskatchewan, Persian darnel is now regarded as an established weed. Some experiments have been conducted to study its germinability and control. It is quite common some ten to fifteen miles south of Scott, where it is a serious pest in the Revenue area. It is plentiful on light land and covers a fairly extensive acreage south of North Battleford (H. A. Friesen).

In the Peace River block of Alberta, the weed appears to be spread generally in the area around Spirit River and extends as far as Wanham and Sexsmith. It is inconspicuous in initial infestations but later tends to become so thick that it chokes out the grain. Since Persian darnel grows about 10 to 12 inches high, much of it remains uncut in the stubble and some seed escapes from the butts of the sheaves. In addition, it is difficult to separate from grain in the ordinary farm fanning mill (E. C. Stacey). It is interesting to note that the specimen collected at Northmark in 1944 by Rowe is the smooth-culmed form, while those collected from the "quite bad" infestation there in 1948 by Shewchuk are of the commoner rough-culmed form. This seems to indicate that the weed is being spread by mass means as a heavy impurity in seed grain or feed.

In August, 1948, a rapid search was made for the weed in three regions near Winnipeg—at St. Norbert, Domain, and North Kildonan, where it had been collected earlier. No plants, however, were located. If the weed had gained prominence in that region, it would have been brought more to the attention of agricultural authorities. The infestation at Makaroff in eastern Manitoba, thought to be introduced in seed grain in 1945, however, was still active in 1948 occurring in patches over about five acres of grain land. The weed is not widely recognized in that area (C. van Drecht), but its occurrence indicates that other outbreaks are to be expected in Manitoba.

The plants from Mortimer Island, a rugged island of the Slate Group about 10 miles off Schreiber along the Lake Superior shore, were undoubtedly introduced with feed-stuffs during lumbering activities. The full collections of the University of Toronto botanists show numerous weed introductions to these islands.' At Guelph, agricultural students located plants (probably escaped from western feed) at the rear of the Veterinary College in July, 1946. The infestations at the Mortimer Island and Guelph sites may not be expected to persist, due, in the former case, to competition from natural vegetation and, in the latter, to competition from students eager to collect classroom material.

SUMMARY

The annual weedy grass which, due to the inadequacies of our floristic manuals, has been passing as *Lolium temulentum* var. *macrochaeton*, *L. rigidum*, *L. rigidum* var. *Duthiei*, or *L. multiflorum* is identified as *L. persicum* Boiss. and Hoh., a species native to south-western Asia. Some of its distinctive characters are the slender rachis, firm lemma with slender awn of equal length, glume equal or slightly shorter than the spikelet, and the sharp-pointed palet which exceeds the lemma in length. Most of the specimens are rough on the culm, but some smooth-culmed plants, which belong to an undescribed form, are also present in Canada.

Persian Darnel first appeared in North America in northeastern North Dakota about 1910 and spread subsequently to various parts of that State. The first Canadian specimens came from Saskatoon in 1923. Since then it has spread westward to the Peace River area of Alberta and eastward into Manitoba. In 1946 it was detected as far east as Guelph, Ontario, and in 1947 was reported from refuse heaps around flour mills at Tewkesbury, England, where Canadian grain was being milled. It is a weed of grain fields in the Prairie Provinces and is apparently being spread in commercial seed and feed grain.

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A SOIL RATING AND CLASSIFICATION FOR IRRIGATION LANDS IN WESTERN CANADA[1]

W. Earl Bowser[2] and H. C. Moss[3]

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The development of extensive irrigation projects in western North America during the first quarter of this century brought into focus many problems hitherto unrecognized. One of them was the realization that irrigated lands varied in their ability to produce and, therefore, in their ability to carry the capital cost of construction. In 1923 the United States government appointed a fact-finding commission to study this and related problems. In submitting its report to Congress in 1924, President Coolidge said in part: "The heretofore adopted repayment plan is erroneous in principle. It fixes an annual arbitrary amount that the farmers must pay . . . regardless of their production. In its place should be substituted a new policy providing that payments shall be assessed . . . in accordance with the crop producing quality of the soil." This need, of assessing the land on the basis of the productive power of the soil, became evident in the Lethbridge Northern Irrigation Project in Alberta early in its history. The first water was applied in 1924 and in 1929 a soil survey was requested of the irrigated lands of this project (1). This survey was under the direction of the late F. A. Wyatt of the Department of Soils of the University of Alberta. A "Table of Ratings", including a soil rating table, was compiled by the Irrigation Council of Alberta and was presented to the Government of Alberta in February, 1930. This soil productivity rating was the one used to rate the soils of the Lethbridge Northern Project. Subsequent to this, the soils on other irrigation projects in southern Alberta were classified and rated (2).

In 1936 the Saskatchewan Soil Survey, at the request of the Water Development Committee of the P.F.R.A., undertook to make soil surveys and to rate the soils in proposed irrigation projects. The following year the Alberta Soil Survey began similar work. Moss (3) outlined the objectives of this type of survey in a paper given at Lethbridge in June, 1939. Since 1936 these two Surveys have classified, mapped and rated in proposed irrigation projects, approximately 400,000 acres by detailed survey and 2,500,000 acres by reconnaissance survey (4).

In the development of a soil rating system specific to irrigable lands on the Canadian Prairies, the same general principles were used as in the rating of land for dry land agriculture, but the emphasis given to the various physical factors was often quite different. As a simple example: In the semi-arid brown zone the heavy textured soils are given top rating for dry land agriculture, whereas for irrigation purposes they rate much lower than do the soils of medium texture.

The ratings reported in this paper are those currently used by the Saskatchewan and Alberta Soil Surveys and are an outgrowth and modification of the original "Table of Ratings" referred to earlier. In 1943 the

[1] Presented to the Soils Section of the Agricultural Institute of Canada at Vancouver, B.C., June, 1949.

[2] Senior Pedologist, University of Alberta, Edmonton. Division of Field Husbandry, Soils, and Agricultural Engineering, Dominion Experimental Farms Service.

[3] Senior Pedologist, University of Saskatchewan, Saskatoon. Division of Field Husbandry, Soils, and Agricultural Engineering, Dominion Experimental Farms Service.

late J. Mutchler, then senior survey engineer for P.F.R.A., requested that the two surveys prepare a uniform classification and rating for irrigation soils. As a result of this request, a meeting was held in Lethbridge, Alberta, in August, 1943, to review the existing data, and to unify the classification systems used by the two Surveys*. The report of this meeting has been the basis for future work (5). Some modifications have been made in individual ratings when necessary but basically the system as reported in this paper is that decided upon at Lethbridge in 1943.

The method described in this paper for classifying soils for irrigation can be used as a fairly specific guide. However, it is not yet possible to evolve a system whereby the effects of all soil factors can be accurately tabulated, related, and applied to obtain a definite mathematical rating. The personal judgment of trained and experienced pedologists is still required in any system of soil rating.

In classifying and rating soils for irrigation the following factors must be considered:

1. *Soil Profile*—The type of soil as shown by the morphology and chemical composition of the profile.
2. *Type of Geological Deposition* of the parent material with special reference to its uniformity.
3. *Soil Texture*—of both surface and subsoil. In relation to the subsoil, consideration must be given to a depth of at least five feet.
4. *Salinity*—The amount, kind and position of the salts in the profile.
5. *Degree of stoniness.*
6. *Wind and water erosion*—if any.
7. *Topography* and its associated drainage pattern.

In rating any soil it is imperative that all the above factors receive recognition and also that no one factor gets recognition in more than one place.

1. *The Soil Profile*

The rating of this factor applies primarily to profiles of the brown and dark brown soil zones since it is considered that most of the irrigation development has been and will be in these zones. The type of soil profile has a bearing on the vertical movement of water through the soil and also on the conditions affecting plant growth. Only the more extensive profile types are listed in this paper; other types will and do occur.

(a) The regional or normal profile—namely, the brown earth and chestnut earth profile. *Rating 100.*

(b) Alluvium. (Immature profiles of river flood plains). *Rating 100.*

(c) The solonchak (saline) profile. Structurally this profile *rates 100.* Deductions, however, must be made for the salt content and this is taken care of under the section on "Salinity".

(d) Solonetzic or solodic profile. These are soils that show some development of the heavy compact B horizon. *Rating 80-90.*

* The following attended this meeting: J. Mitchell, University of Saskatchewan; J. D. Newton, University of Alberta; J. L. Doughty, Dominion Soil Laboratory, Swift Current; W. E. Bowser and H. C. Moss, Dominion Experimental Farms Service. E. S. Hopkins, Associate Director, Dominion Experimental Farms Service, attended the first session. F. A. Wyatt was unable to attend but assisted in subsequent discussions carried on by correspondence.

(e) Solodized solonetz, the hard columnar-pan profile. Shallow and deep variations of this profile occur as well as varying degrees of hardness of the B horizon. Eroded pits are often associated with this soil type. *Rating from 60-80.*

(f) Calcareous earth profile. This soil has a weakly developed B horizon that is usually calcareous. *Rating 90.*

(g) Very calcareous profile. This soil has a limy A horizon directly over the B_{ca} horizon. The rating given depends on the amount of carbonate and its closeness to the surface. *Rating 70-90.*

2. *Type of Geological Deposition*

The kind of geological deposition of the parent material in so far as it influences the movement of water through this material affects the value of soil for irrigation purposes. This factor is concerned primarily with the lateral movement of water and the consequent development of seepage (vertical movement is considered under "Profile Types" and "Soil Texture").

The following main types of surface deposits are encountered:

(a) Glacial lacustrine deposits, medium to heavy textured, uniform throughout their depth. *Rating 100.*

(b) Alluvial-lacustrine and aeolian deposits, light to medium textured, uniform throughout. *Rating 100.*

(c) Glacial till—somewhat variable. There is very little information on the movement of irrigation water through glacial till primarily because few glacial areas have been irrigated. Since the material in these deposits is usually quite variable, and also as the configuration of the particles in a till deposit may be quite different to the configuration in an alluvial or a lacustrine deposit, it is difficult to postulate whether appreciable lateral movement of water will take place or not. It is expected that some seepage will occur and that the somewhat irregular topography of the till areas will facilitate seepage. It is suggested that the ratings be based upon the amount of variability and on the degree of compaction. *Tentative rating 60-80*—subject to revision when the behaviour of till under irrigation is better known.

(d) Alluvial deposits—variable throughout depth (that is, they contain lenses of widely different textures as well as gravel). *Rating 50-80.*

(e) Sorted or modified residual deposits. The depth to consolidated bedrock and the nature of the bedrock must be considered. *Rating 20 to 100* (that is, the 20 rating would apply to soils with less than 1 foot of profile over the consolidated bedrock).

(f) Glacial outwash; gravelly and stony. *Rating 20 to 50.*

3. *The Soil Texture*

The soil texture is a very important factor in irrigation. The ratings given below assume the "normal" texture gradient for the profile type; that is, in most profiles a gradual increase in texture weight with depth.

Where an abrupt textural difference occurs which is not taken care of in the parent material or profile factor, it must be considered here and will modify the rating given the surface texture.

There have been considerable changes in kind of crops grown and in cropping practices over the years and this has necessitated changes in the texture rating. In general this has meant a raising of the rating for some of the light and medium textures. The following rates apply to the more frequently occurring textures:

Silt loam	100
Loam	90–100
Silty clay loam	90
Clay loam	90
Very fine sandy loam	90
Sandy clay loam	90
Fine sandy loam	80–85
Silty clay	75–85
Sandy loam	70–75
Clay	50–70
Coarse sandy loam	60–65
Loamy sand	50–60
Highly dispersed clay	30–50
Sand	30–50
Gravel	20

4. *Salinity*

It is very difficult to accurately forecast the amount and extent of salt (alkali) damage that may develop with the application of irrigation water. The amount of salt present in the soil and the uniformity or lack of uniformity of the parent material are the principal determiners of future damage. Some general estimation, however, can be made. The relative uniformity of the parent material is given recognition in Section 2 above. The present section deals with the amount and kind of salt present. In general it is considered that soils containing over 1 per cent of water-soluble "white alkali" salts in the upper two feet (exclusive of calcium sulphate) are unsuitable for irrigation. Small areas of soil with this high a salt content, lying within large areas of desirable land, will quite possibly be irrigated and may produce some fodder; however, it would be unwise to recommend the irrigation of large tracts of this type.

In rating the salinity factor, consideration must be given to the texture, the profile features and the general fertility of the soil, as these may modify the final rating given.

For "black alkali", concentrations of sodium carbonate of 0·1 per cent or over are regarded as too high for satisfactory crop growth. Even slight amounts of "black alkali" reduce the productive value of the soil. In general any soil with a pH value above about 8.8 in the upper two feet is considered dangerous.

Rating for White Alkali

"None" to "traces"	Rating 100
0·2 to 0·4 per cent	Rating 75–95
0·4 to 0·7 per cent	Rating 50–85
0·7 to 1·0 per cent	Rating 25–60
Over 1·0 per cent	Rating 20–30

The highest ratings apply to the heavier textured soils, the lowest rating to the light textured soils. These ratings apply to the upper 24 inches of soil. High concentrations below this depth are a potential source of "alkali" trouble, and such a condition should be covered in the report and some deductions made for this in the rating. In soils high in sulphate and in which soluble sodium and magnesium are considerably higher than calcium, the limits reported in this table must be reduced considerably.

5. *Degree of Stoniness*

The degree of stoniness affects the cultivation of the land rather than its irrigability. It is a factor, however, that must be considered. The ratings used are quite similar to those used by the soil survey for dry land agriculture rating.

No stones	Rating 100
Few stones	Rating 85–95
Moderately stony	Rating 60–85
Very stony	Rating 30–60
Excessively stony	Rating 20

6. *Erosion*

Loss of top soil by erosion reduces the value of the land and must receive consideration. Considerable judgment must be used in the application of this factor since a given loss in one soil type may not be of equal value to loss in another soil type.

The rating given varies from 100 for relatively no loss, to about 60 if all the A horizon is removed. The patchy removal of the A horizon in the solodized profile is considered under this factor and is rated on the basis of percentage loss to the base figure of 60.

Very severe erosion, such as deep wind-eroded pits and water-cut gullies, must receive separate consideration.

7. *Topography*

The final topographic classification must be made from plane table sheets to determine exact irrigable acreage, size of field, mileage of canal and percentage slope. However, for proposed projects it is generally necessary for the soil surveyor to make a preliminary topography classification. The classification and ratings listed below were compiled by checking topography classes against plane table sheets and lumping all the deductions made for size of field, percentage slope etc. into one topographic factor. In general, this factor is a rating of the irrigable portion of the parcel, and is only indirectly affected by the amount of non-irrigable land.

1. *Level to very gently sloping*	*Rating*
0·2 per cent to 2 per cent uniform slope—all irrigable.....	90–100
2. *Very gently undulating*	
Irregular hummocky surface that requires levelling. With levelling most of area irrigable—0·2 per cent to 2 per cent slope.....	70–90

3. *Gently sloping*

Frequency of 1 or less roll per half mile. All irrigable on assumption that water will reach highest point..... 70–90

4. *Gently undulating*

Up to three rolls per half mile; slopes may be in more than one direction. Some non-irrigable land—2 per cent to 5 per cent slope..... 60–75

5. *Roughly undulating*

Four or more rolls or knolls per half mile. Considerable non-irrigable land—2 per cent to 5 per cent slope..... 20–55

6. *Flat and depressional land*

Usually less than 0·1 per cent slope. Its value will depend largely on the feasibility of constructing drains..... 20–50

7. *Gently rolling*

Irregular surface, and moderately sloping regular surface. Considerably non-irrigable to all non-irrigable..... 20–50

8. *Rolling, hilly and steeply sloping*

This includes areas that are rough, broken and eroded..... 15–35

When the above seven factors are individually rated, these ratings are all multiplied together to give the final rating. The final ratings are then fitted into the groups given in Table 1. This grouping is then superimposed on the basic soil map or is reported on a separate map.

TABLE 1.—CLASSIFICATION TABLE FOR RATING SOILS FOR THE PURPOSE OF IRRIGATION

Group	Description	Rating	Map colour
1	Very good soils	100–73	Blue
2	Good soils	72–53	Green
3	Fair soils	52–40	Yellow
4	Poor or doubtful soils, or soils of limited use	40–25	Orange
5	Unsuitable	Below 25	Red

It is noted that there is an increase in category range with each higher class. There is a range of 27 points in Class I land, 19 points in Class II and 12 points in Class III. It is possible to subdivide, if required, at least the two top classes.

The following example illustrates the use of this rating system. Chin light silt loam is a regional brown earth profile of alluvial-lacustrine deposition. It is the dominant profile in the St. Mary's development project. An average Chin light silt loam rates about 100 for profile, 100 for texture, 90 for topography, 90 for salinity and 90 to 95 for the deposition factor. Multiplying these together gives a final rating of about 75; that is the lower limit of Class I. Any additional detrimental variation, as for example in topography, would place an area down into Class II.

It is known that certain changes may occur within the soil profile as the result of irrigation. For example, in the original levelling of the micro-relief certain changes in the surface texture occur. Wyatt, in a paper presented to the Western Society of Agronomy in June 1939, lists the following changes:

(1) Change in soil volume
(2) Change in soil structure
(3) Change in fertility
(4) A translocation and possible concentration of the water soluble salts.

This last-mentioned change is also reported by Marshall and Palmer (6). These factors cannot be fully assessed prior to irrigation and some reclassification of problem areas may be necessary subsequent to irrigation.

ACKNOWLEDGMENTS

The authors wish to emphasize that the information presented in this paper is a contribution of the Alberta and Saskatchewan Soil Surveys, and that all those who have been associated with irrigation soil surveys in the two provinces during the past twenty years have contributed in some measure to this subject.

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EFFECT OF INADEQUATE BROOD SOW RATIONS ON THE PRENATAL AND POSTNATAL DEVELOPMENT OF THE PROGENY[1]

L. W. McElroy[2] and H. H. Draper[3,4]

Department of Animal Science, University of Alberta, Edmonton, Alberta.

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INTRODUCTION

Interest in brood sow nutrition has been stimulated by the results of a number of studies (1, 2, 6, 7, 8, 9) recently conducted in the United States which have shown that rations, formulated to contain adequate protein, minerals, vitamins A and D, and energy for growth, may be strikingly inadequate for the support of normal reproduction and lactation in brood gilts and sows maintained continuously in dry lot. These, and other studies, emphasize the importance of earlier observations regarding the value of pasture and alfalfa hay in brood sow nutrition, and demonstrate that rations which are satisfactory for pigs being grown and fattened for market may be deficient in nutrients required for normal gestation and lactation.

Although reproduction and lactation failures of the severity of those reported by American observers are not normally encountered by Canadian swine producers who make proper use of the available grains and supplements, serious losses do occur in herds in which sows are maintained under conditions approaching continuous dry lot feeding on rations containing very limited amounts of protein, mineral or vitamin supplements.

The present report outlines the results of a series of experiments initiated in the summer of 1944 to obtain data on the performance of an experimental group of sows maintained over an extended period in dry lot on a ration composed simply of oats, barley, ground limestone and salt, as contrasted to that of a comparable control group fed oats and barley supplemented with a protein-mineral mixture, feeding oil and pasture in season. Representative gilts from both groups of sows, after being grown out in dry lot to a weight of from 200 to 225 lb. on a ration of oats and barley supplemented with a protein-mineral mixture, but not with feeding oil, were maintained on the same ration as that fed their respective dams. Data are presented to show that the performance of the second generation females fed the experimental deficient ration after reaching breeding age was inferior to that of their dams as measured by numbers of pigs farrowed and weaned, and that their productivity was not fully restored by subsequent supplementation with either alfalfa meal or mixed protein-mineral supplement, feeding oil and pasture.

[1] This study was conducted with the aid of a grant from Burns and Company, Limited, Calgary, Alta.

[2] Associate Professor of Animal Husbandry.

[3] Lecturer in Animal Husbandry, 1948–49. Present address: Division of Animal Nutrition, University of Illinois, Urbana, Ill.

[4] Part of the data in this paper were taken from a thesis submitted by H. H. Draper in partial fulfilment of the requirements for the degree of Master of Science.

EXPERIMENTAL

SECTION I. REPRODUCTION STUDIES

The experiments subsequently described are divided into three series, A, B, and C, according to the nature of the experimental ration. In Series A, comprised of five farrowing seasons, the ration for the experimental group contained grains and minerals. In the Series B experiments, covering three farrowing seasons, the ration of grains and minerals was supplemented with alfalfa meal. During Series C, consisting of two farrowing seasons, all sows, including those previously deprived of supplementary protein and pasture, were maintained on the control ration which included protein supplement, minerals, feeding oil and pasture in season. With one exception, noted below, the experimental rations were fed continuously.

Series A Experiments

Object

To obtain data on the long-term performance of sows deprived of pasture and greenfeed and fed a ration considered deficient in protein, vitamins A and D, and possibly other factors, as compared to that of sows fed a good quality ration including pasture during the summer.

Procedure

Experiment 200—Summer 1944

Two groups of four two-year-old purebred Yorkshire sows of similar breeding were used in this experiment. They and their dams had previously been maintained on a ration made up of coarse grains, mixed protein-mineral supplement, and either pasture or alfalfa hay plus fish oil.

With the exception of a five-month period (see Experiment 200B) the four original sows in each group were fed the rations shown in Table 1 from June 1944 to November 1946. As indicated below, a number of daughters of the original sows were placed on the same feeding regime as their dams after they had reached breeding age.

TABLE 1.—RATIONS—SERIES A EXPERIMENTS

	Group I—Control		Group II—Experimental
	On pasture	In dry lot	
	%	%	%
Ground Oats	47	44	49
Ground Barley	47	44	49
Mixed Supplement*	6	12	—
Feeding Oil**	—	½ oz. per sow per day	—
Iodized Salt	—	—	1
Ground Limestone	—	—	1

* The mixed supplement was composed of: Tankage 50, linseed oil meal 25, alfalfa meal 15, ground limestone 5, and iodized salt 5 pounds per 100 pounds of mixture.

** The feeding oil was guaranteed to contain 1500 I.U. of vitamin A and 200 I.U. of vitamin D per gram.

The crude protein content of the rations of both groups varied considerably with different sources of coarse grains, but analyses indicated that on an air-dry basis the protein content of the dry lot ration for the control group ranged from approximately 14.0 to 15.0 per cent, while that of the experimental group varied from 10.5 to 11.5 per cent.

Group I received cereal or rape pasture during the summer. The experimental sows of Group II were subjected to continuous dry lot feeding in vegetation-free yards. Sows of both groups were moved into the piggery for farrowing and the first three or four weeks of lactation.

All young pigs were treated with three weekly doses of reduced iron and 3 c.c. of feeding oil containing 1500 I.U. of vitamin A and 200 I.U. of vitamin D per gram.

Experiment 200B—Winter 1944–45

Owing to a critical labor shortage it was necessary to maintain both groups of sows on a gestation ration consisting of oats 60, barley 34 and mixed protein-mineral supplement 6 per cent. At farrowing they were returned to their respective rations as outlined for Experiment 200.

Experiment 208—Summer 1945

As for Experiment 200.

Experiment 208B—Winter 1945–46

Three gilts were selected from the second litters of each group and added to their respective lots. The procedure of Experiment 200 was continued.

Experiment 215—Summer 1946

Two additional second-generation gilts were included in each group, and a number of the original sows were discarded so that only one of these remained in Group I and two in Group II.

Results and Discussion

The farrowing and weaning records of the experimental and control groups for the five experiments of Series A are summarized in Table 2.

Despite the absence of protein supplement, feeding oil and pasture from the ration fed the experimental group no serious breeding difficulties were encountered during these experiments. As indicated in Table 2, the control sows farrowed an average of 2.7 more live pigs than those of the experimental group, and by weaning the disparity in litter size had increased to 3.6 pigs. While the control sows weaned 74 per cent of their pigs and the experimental sows only 55 per cent, the progeny of the latter group that survived to weaning age were as heavy at that time as those of the former. That the vigour of the pigs from the test sows at weaning was impaired, however, was indicated by post-weaning losses of 22 per cent for the experimental group and 13 per cent for the controls.

In spite of the continuous absence of fish oil in the experimental ration, no gross manifestations of prenatal vitamin A deficiency, such as malformed or stillborn pigs, were observed. To what extent the weakness of many of the progeny of the test sows and their susceptibility to infection were attributable to a deficiency of this vitamin is speculative.

TABLE 2.—FARROWING AND WEANING RECORDS—CONTROL VS. EXPERIMENTAL SOWS, SERIES A

	Number sows bred	Number sows farrowed	Total number pigs born		Average number born alive*	Average birth weight, lb.	Number weaned		Per cent weaned	Age at weaning, days	Average weaning weight, lb.
			Alive	Dead			Total	Mean*			
Experiment 200											
Control	4	3	38	1	12.7	2.8	28	9.3	74	56	26.7
Experimental	4	4	40	1	10.0	2.5	24	6.0	60	55	23.1
Experiment 200B											
Control	4	4	48	2	12.0	2.5	41	10.3	85	59	27.9
Experimental	4	3	27	2	9.0	2.7	17	5.7	63	54	23.6
Experiment 208											
Control	4	3	33	2	11.0	2.5	19	6.3	58	55	23.1
Experimental	4	4	38	0	9.5	2.6	11	2.8	29	56	21.4
Experiment 208B											
Original sows:											
Control	4	4	41	3	10.2	2.4	27	6.7	66	48	25.1
Experimental	4	4	37	0	9.2	2.8	21	5.2	57	59	31.7
Daughters:											
Control	3	3	20	1	6.7	2.6	15	5.0	75	57	27.7
Experimental	3	3	15	4	5.0	2.6	13	4.3	87	60	28.5
Experiment 215											
Original sows:											
Control	1	1	14	0	14.0	2.0	12	12.0	86	67	24.4
Experimental	2	2	19	1	9.5	3.0	14	7.0	74	61	33.7
Daughters:											
Control	5	4	48	0	12.0	2.5	38	9.5	79	62	24.3
Experimental	4	4	24	2	6.0	2.7	10	2.5	42	66	23.7
Totals and Means											
Control	25	22	242	9	11.0	2.5	180	8.2	74	57	25.9
Experimental	25	24	200	10	8.3	2.7	110	4.6	55	58	26.7

* Basis no. sows farrowed.

First vs. Second Generation

A comparison of the farrowing and weaning records of the first and second generation sows, control and experimental, is shown in Table 3.

TABLE 3—FARROWING AND WEANING RECORD—FIRST VS. SECOND GENERATION, SERIES A

Group	Generation	Number litters farrowed	Number pigs born alive		Number weaned		Per cent weaned
			Total	Mean	Total	Mean	
I—Control	First	15	174	11.6	127	8.5	73
II—Experimental	First	17	161	9.5	87	5.1	54
Difference in favour of Group I		−2	13	2.1	40	3.4	19
I—Control	Second	7	68	9.7	53	7.6	78
II—Experimental	Second	7	39	5.6	23	3.3	59
Difference in favour of Group I		0	29	4.1	30	4.3	19

The effect of the experimental regime on the second generation may be gauged by comparing the performance of the first and second generations of the test sows with that of the controls. The difference in litter size of 1.9 pigs between generations of control sows is assumed to be due to the normal decrease in the size of first litters. The corresponding difference of 3.9 pigs for the experimental sows shows an additional decrease of 2.0 pigs per litter which may be charged against the effect of the test ration. The disastrous consequences of the experimental regime are indicated by the fact that the second generation test sows weaned an average of only 3.3 pigs per litter.

Series B Experiments

The data presented above for the experiments included in Series A show that continuous feeding of a ration of grain, ground limestone and iodized salt to the brood sows in the experimental group led to a marked decline in the number of pigs weaned by the sows of this group. The series B experiments, covering a period of three farrowing seasons, were conducted to determine whether the addition of alfalfa meal to the ration of these sows would lead to any improvement. The rations fed to Group II during this period were as follows:

	First 6 months	Succeeding 12 months
	%	%
Oats	43	41
Barley	43	41
Alfalfa meal	12	16
Ground limestone	1	1
Iodized salt	1	1

The alfalfa meal used was of medium quality and contained an average of 14 per cent protein on an air-dry basis. The protein content of the complete ration, as estimated from intermittent analyses, ranged from 11 to 12 per cent.

The sows and gilts used were daughters of sows in Group II of Series A. Four out of nine of these daughters had farrowed either once or twice while they were being fed the original Group II ration of grain, ground limestone and salt. The remaining five farrowed for the first time after being fed this ration supplemented with alfalfa meal during pregnancy. The control sows of group I were also the daughters of the original group I—Series A animals, and they were continued on the feeding regime followed in this group during the Series A tests.

Results

The average results for the three farrowing seasons included in the period of 18 months during which the ration of group II was supplemented with alfalfa meal are summarized in Table 4.

TABLE 4.—EFFECT OF ALFALFA MEAL SUPPLEMENTATION

	Group I (control)	Group II (alfalfa meal)
Number litters possible	20	18
Number litters born	18	16
Per litter:		
Average number pigs born alive	11.8	9.9
Average number pigs born dead	0.6	0.5
Average number pigs weaned	7.9	6.1
Per cent pigs weaned	67	61
Average weaning weight, lb.	24.6	19.7
Average number pigs marketed	7.0	4.9
Per cent pigs marketed	61	50

Comparison of the averages listed for Group II in Tables 4 and 2 for numbers of pigs born and weaned per litter shows that 1.6 more pigs were farrowed and 1.5 more were weaned by the sows in the Series B experiments than by those in the Series A experiments. These results, obtained following the addition of alfalfa meal to a ration of cereal grains, salt and ground limestone, suggest that alfalfa meal supplementation may bring about some improvement in production performance even with sows or daughters of sows that have been fed an obviously inadequate ration over an extended period. However, from a comparison of the results for Groups I and II in Table 4 it is apparent that supplementation simply with alfalfa meal failed to raise the production performance of the sows in Group II to a normal level. Pigs from these sows averaged 19.7 lb. in weight at weaning and post-weaning death losses were high, so that only 4.9 pigs out of each litter reached market weight.

The chief beneficial effect of alfalfa meal supplementation, under the conditions of these experiments, appeared to be an increase in the number of pigs born per litter. A greater number of pigs were weaned per litter by the sows in group II of the Series B experiments than by those in the

same group in the Series A trials, but this increase in litter size at weaning was, to a large extent, offset by the fact that the average weight at weaning was 7.0 lb. less per pig.

Series C Experiments

These experiments were conducted to determine the improvement in reproductive performance that might result from feeding a more complete ration, including pasture in season, to sows selected from group II of Series B. Sows from Group I of Series B were used as controls. Both groups were fed the same ration, viz. that used for Group I in the Series A and B experiments. Records are complete for two farrowing seasons—the fall of 1948 after the sows of both groups had been on cereal and rape pastures for approximately four months, and the spring of 1949. Farrowing, weaning and marketing records for the two seasons are summarized in Table 5.

TABLE 5.—EFFECT OF FEEDING CONTROL RATION TO SOWS OF GROUP II OF SERIES B

	Group I	Group II
Number litters possible	13	11
Number litters born	10	8
Per litter:		
Average number pigs born alive	11.5	11.1
Average number pigs born dead	0.5	0.0
Average number pigs weaned	8.9	8.2
Per cent pigs weaned	77	74
Average weaning weight, lb.	26.9	21.8
Average number pigs marketed	8.5	7.2
Per cent pigs marketed	74	65

The trend toward better performance in Group II during the Series C experiments was similar to that obtained in the Series B trials. That is, there was a further increase in litter size to an average of 11.1 pigs as compared to 11.5 farrowed by the sows of Group I. Improvement is apparent also in the percentage of pigs weaned in Group II—74 per cent during the Series C trials as compared to 61 per cent for Series B and 55 per cent for Series A. The average weaning weights remained low at 21.8 lb. and post weaning death losses in Group II were 9 per cent as compared to 3 per cent in Group I. These results, obtained with sows characterized by a previous history of poor nutrition, suggest that the effects of feeding inadequate rations to brood sows over an extended period may be at least semi-permanent in nature.

SECTION II. PROGENY FEEDING TRIALS

Object

To augment the reproduction data which have been presented in Section I, five feeding trials (Nos. 208, 208B, 215, 218 and 221) were conducted to ascertain the effect of the ration fed to the sows during the Series A and B experiments upon the growing and fattening performance of their progeny.

Procedure

Representative weanling pigs from each group of sows were allotted as uniformly as possible with respect to sex, weight, dam, condition and type, to lots of from five to seven pigs each. The pigs were housed in a piggery without access to soil or sunlight. Straw was used for bedding. In some instances the numbers of test pigs available did not permit as high a degree of uniformity in allotment as might have been desirable, but continued repetition of the trials resulted in the establishment of averages which are believed to constitute a fair basis for comparison of the growth and fattening performances of progeny of the control and experimental sows. Weights were recorded at the beginning of the experiment and every fourteen days thereafter until the pigs reached a market weight of approximately 200 pounds.

Each feeding trial was divided into two periods: Period I, from weaning to 110 lb.; and Period II, from 110 lb. to market weight. The basal rations fed are listed below:

	Period I	Period II
	%	%
Ground oats	35	10
Ground barley	53	84
Mixed supplement*	12	6

* The mixed supplement was composed of: Tankage 40, linseed oil meal 35, fish meal 15, ground limestone 5, and iodized salt 5 pounds per 100 pounds of mixture.

The average protein contents of the above rations on an air-dry basis were 14.4 per cent for the first period and 12.4 per cent for the second. It will be noted that the rations for both periods might be regarded as deficient in vitamins A and D. For purposes of comparison, the two lots of Experiment 221 and the first and third lots of Experiment 218 (see Table 6), control and experimental, were given fish oil at the rate of 4 c.c. per pig per day.

Results and Discussion

A summary of the results of the five feeding trials is presented in Table 6.

Although the differences in the feed lot performance between the pigs from the control and test sows were small, they were relatively consistent. According to Student's t test for unpaired values, the average differences of 0.09 lb. per day in daily gain and 19.9 lb. feed consumed per 100 lb. gain are highly significant (t = 19.83 and 3.67 respectively).

Occasional instances of staggering and muscular incoordination were observed among the pigs from sows of both groups. Pigs that exhibited only mild symptoms of incoordination were left untreated and in most cases made a gradual recovery without any serious loss of appetite or decrease in rate of growth. The most severe cases were treated individually with feeding oil. Recovery was rapid following treatment and the attacks were attributed to vitamin A deficiency. No cases of incoordination were observed in the groups that received feeding oil in the ration.

TABLE 6.—RESULTS OF FEEDING TRIALS—PROGENY OF CONTROL AND EXPERIMENTAL SOWS

Group	Lot No.	Number of pigs	Average initial weight	Average final weight	Average daily gain	Average feed per 100 lb. gain
			lb.	lb.	lb.	lb.
Experiment 208						
Control	1	6	29.2	195.3	1.23	369.0
Experimental	1	6	29.3	193.3	1.05	400.5
Experiment 208B						
Control	1	7	42.4	202.6	1.43	378.2
Experimental	1	5	36.3	201.4	1.31	397.9
Control	2	9	26.1	194.6	1.29	369.2
Experimental	2	6	24.2	194.7	1.24	381.6
Experiment 215						
Control	1	7	35.3	200.4	1.12	378.6
Experimental	1	5	34.0	194.6	1.05	416.1
Control	2	5	29.8	199.2	1.16	391.6
Experimental	2	6	27.0	201.2	1.11	365.0
Experiment 218						
Control	1*	7	24.4	194.3	1.07	367.4
Experimental	1*	5	21.0	189.6	1.04	381.1
Control	2	6	34.3	209.2	1.20	375.2
Experimental	2	7	31.1	194.3	1.01	420.0
Control	3*	7	39.4	201.1	1.16	380.2
Experimental	3*	5	42.2	202.2	1.22	408.6
Experiment 221						
Control	1*	5	45.4	200.8	1.37	377.9
Experimental	1*	5	24.8	195.6	1.20	387.9
Totals and Averages						
Control		59	33.6	199.4	1.22	375.7
Experimental		50	29.8	196.2	1.13	395.6

* Feeding oil containing 1500 I.U. vitamin A and 200 I.U. vitamin D per gram was fed to these lots at the rate of 4 c.c. per pig per day.

From the data accumulated during the reproduction and feeding trial studies, it appears that the effect of the deficient ration fed to the experimental sows was exemplified primarily in their reproduction and weaning performance rather than in the growing-fattening record of the progeny. Growing pigs which survive beyond the weaning stage and are subsequently maintained on a ration of cereal grains supplemented with protein and minerals are evidently capable of performing with moderate success, even though the ration of their dams was of poor quality.

GENERAL DISCUSSION

Considering that the ration fed to the sows in Group II during the Series A experiments was not supplemented with protein or feeding oil, the results obtained were in some respects unexpectedly favourable. Evidently no factors were deficient to such a degree that the ability of the sows to conceive was affected. The incidence of abnormalities at birth was zero, and the number of pigs born dead was the same for the two groups. In accordance with the relative litter size, the average birth weight of pigs from sows of the experimental group was 0.2 lb. greater than that of those

from the control sows. No explanation is apparent for the fact that, despite a continued absence of a vitamin A supplement in the test ration, no gross evidence of a prenatal deficiency of this vitamin was observed in the progeny of the sows in Group II. Secondary infections, particularly those of the respiratory tract, were common during the suckling and post-weaning stages.

Gwatkin (3) and Gwatkin and Plummer (4, 5) have reported on the effect of continuously feeding a ration of grain, salt and ground limestone to brood sows and their offspring. Although data are reported for only a small number of sows, they showed a high incidence of breeding difficulties, of stillborn pigs and of deaths before weaning. Progressive depletion in succeeding generations was also demonstrated, the losses prior to weaning in the first to third generations being 26, 60 and 100 per cent respectively.

In the present experiments the main impact of the deficient regime was registered during the lactation period. Many of the pigs from the test sows became thin, emaciated and diarrhoeic within a few days after birth, and by weaning age the incidence of mortality reached 45 per cent. Of the remainder, 22 per cent died during the post-weaning period, leaving a group whose performance during the growing and finishing stage compared relatively favorably with that of the control pigs.

It is difficult to state accurately to what extent a deficiency of milk production existed on the part of the test sows, but it is doubtful if there was a shortage during early lactation. On the other hand, the milk supply of some of the sows became meagre during the later stages of the nursing period.

An attempt was made to assess the financial significance of the losses incurred in these experiments through the continuous use of the deficient sow rations fed to Group II in the Series A and B trials. Gross revenues from the sale of pigs marketed from the sows of groups I and II were calculated from current prices. Deductions were made for feed, labour, boar service, sow replacement, interest and depreciation on investment in buildings, etc., and, in the case of Group I, for pasture and fencing. The calculated net return from group II over a period of $3\frac{1}{2}$ years was only one-quarter that from group I.

SUMMARY

Experiments were conducted to determine the effect of maintaining an experimental group of sows continuously on a ration consisting of small grains, iodized salt and ground limestone, as compared to the effect of maintaining a control group on a common practical ration which included coarse grains, mixed protein-mineral supplement, feeding oil, and pasture in season.

The breeding efficiency of the experimental sows as measured by their ability to conceive was not impaired by the deficient ration; but their prolificacy, as compared to that of the control group, was reduced by 2.7 live pigs per litter. No abnormal or stillborn pigs were observed. Mortality among the progeny of the test sows was high during the lactation and post-weaning periods. The deleterious effect of the experimental regime was more pronounced in the record of second generation sows than in that of the first. In terms of average daily gains and feed consumption per 100 lb. gain, the feeding performance of the progeny of the control sows was somewhat superior to that of the progeny of those in the experimental group.

The addition of alfalfa meal to the ration fed to the sows of the experimental group caused an increase in average litter size and number weaned, but the vigour and weaning weights of the progeny were not improved. When the control ration, including pasture in season, was fed to the depleted sows of the experimental group, a further increase was obtained in the numbers of pigs born and weaned per litter, but the average weaning weights remained low.

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